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Assessment of Industrial Hazardous Waste Practices, Rubber and Plastics Industry Plastic Materials and Synthetics Industry

Foster D. Snell, Inc, Florham Park, N.J.

Prepared for

Environmental Protection Agency, Washington, D.C.

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ASSESSMENT OF INDUSTRIAL HAZARDOUS WASTE PRACTICES, RUBBER AND PLASTICS INDUSTRY

Plastic Materials and Synthetics Industry

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16. ABSTRACT

This industry study is one of a series under the Office of Solid Waste Management Program of the Hazardous Waste Management Division, U.S. Environmental Protection Agency. The report concentrates on the rubber and plastics industry. It characterizes these industries in terms of number, location, size and age of plants, products, processes, etc.; identifies and quantifies those wastes which are or may be generated by these industries; describes current practices for treatment and disposal of potentially hazardous wastes; determines the control technologies which might be applied to reduce hazards presented by these wastes upon disposal; and estimates the cost of control technology implementations.

The information presented in the report was acquired from a review of published information; trade association participation; personal contacts; visits to various plants and corporate offices of germane companies; waste sample analysis; and the application of an econometric model to project waste loads for 1977 and 1983.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Control Costs Hazardous Wastes Industrial Wastes Plastics Industry Residues Rubber Industry Sludges Solid Wastes Waste Generation Factors	Chemical Treatment Hazard Potential Incineration Land Filling Lagooning Resin Manufacture Stream Separation Toxicity	

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- Rubber Manufacturers Association
- International Institute of Synthetic Rubber Producers
- Manufacturing Chemists Association
- Textile Economics Bureau
- Society of the Plastics Industry

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II. PLASTIC MATERIALS AND SYNTHETICS INDUSTRY -- SIC 282

This chapter characterizes and discusses the industry structure, the manufacturing processes, the total wastes generated and their treatment and disposal technologies and the associated costs for the potentially hazardous wastes identified for the Plastic Materials and Synthetics Industry, SIC 282.

The chapter's contents are presented as follows:

- SECTION 1 -- INTRODUCTION AND GENERAL DESCRIPTION OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY
- SECTION 2 -- CHARACTERIZATION OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282
- SECTION 3 -- PROCESS DESCRIPTIONS, WASTE STREAM IDENTIFICATION AND WASTE CHARACTERIZATION AND QUANTIFICATION, SIC 282
- SECTION 4 -- TREATMENT AND DISPOSAL TECHNOLOGY FOR POTENTIALLY HAZARDOUS WASTES GENERATED BY THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282
- SECTION 5 -- COST ANALYSIS FOR THE TREATMENT AND DISPOSAL OF POTENTIALLY HAZARDOUS WASTES, SIC 282.

All tables and figures follow the text immediately after they are discussed.

1. INTRODUCTION AND GENERAL DESCRIPTION OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY

The following industry segments are included within SIC 282:

Plastic Materials and Resins	SIC 2821
Synthetic Rubber	SIC 2822
Cellulosic Man-Made Fibers	SIC 2823
Organic Fibers, Non-Cellulosic	SIC 2824.

Tables and figures discussed, follow in the section's text.

1.1 In 1972, SIC 282 Industries Employed Over 160 Workers And Produced Approximately $10 Billion In Shipments

Table II-1 shows the number of employees, value added, value of shipments, and approximate number of establishments and companies for the plastic materials and synthetics industry in 1972. It also presents the relative importance of each of the SIC 282 segments in terms of employment and value added. The table is based on the 1972 Census of Manufacturers and indicates:

- These industries have approximately 462 establishments with 70% within SIC 2821. Similarly, of the 289 companies reporting in SIC 282, 66% are classified in SIC 2821.
- In terms of value added by manufacturers and value of industry shipments, SIC 2821 is also most important.
- Only in terms of all employees is SIC 2824 the largest.

TABLE II-1

1972 STRUCTURE OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282

SIC Code(1)	All Employees		Value Added by Manufacture		Value Of Industry Shipments		Approximate Number of Establishments		Companies(2)	
	(thousand)	(% of SIC 282)	($ million)	(% of SIC 282)	($ million)	(% of SIC 282)	(number)	(% of SIC 282)	(number)	(% of SIC 282)
2821	54.8	(33.8)	2,160.5	(43.8)	4,478.2	(45.7)	323	(70.0)	191	(66.0)
2822	11.8	(7.3)	491.7	(10.0)	1,089.4	(11.1)	59	(13.0)	50	(17.3)
2823	19.0	(11.7)	252.7	(5.1)	627.9	(6.4)	20	(4.0)	13	(4.5)
2824	76.3	(47.1)	2,031.1	(41.1)	3,601.4	(36.8)	60	(12.0)	35	(12.2)
282	161.9		4,936.0		9,796.9		462		289	

Note:

(1)

SIC Codes by industry group and industry are:

2821	Plastic Materials and Resins
2822	Synthetic Rubber
2823	Cellulosic Man-Made Fibers
2824	Organic Fibers, Non-Cellulosic
282	Plastic Materials and Synthetics

(2)

A company, as the term is used in the Census of Manufacturers, is a business organization consisting of one establishment or more under common ownership or control.

Source: U.S. Bureau of Census, Census of Manufacturers, 1972 Industry Series: Plastic Materials, Synthetic Rubber and Man-Made Fibers, MCT2(2)-28B, U.S. Government Printing Office, Washington, D.C., 1974.

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1.2 Many Of The Production Units In This Industry Are Part Of Large Plant Complexes

The Census Bureau classifies or segments industries in terms of establishments. This technique does not in many instances represent the proper method for reporting for the purposes of this study. This is due to the fact that establishments as reported in the Census may be manufacturing several classes of products both within and outside the scope of this study. This situation is the rule rather than the exception for the major plastic materials, synthetic rubbers and spinning establishments classified within SIC 282.

Foster D. Snell, Inc., therefore, identified the the number of production units within the establishments or plant complexes producing materials classified in each of the four industry segments of SIC 282. For the purposes of the study industry structure and waste quantification are reported in terms of production units so that a more realistic picture of SIC 282 could be provided.

A consequence of this approach is that a greater number of production units are reported in each four digit SIC by Snell than establishments as reported by the Census.

1.3 Polymerization And Spinning Are The Two Major Operations In SIC 282 Used For The Manufacture Of Their Products

Polymerization is the chemical reaction whereby repeating units of one or more molecular species are combined to form a large molecule. While this process can take several forms, e.g., solution, suspension, emulsion, etc., it is basic to the manufacture of all products in this industry.

Spinning operations are significantly different from the polymerization process in terms of equipment and type of physico-chemical changes occurring in the product formation. Fundamentally, this process is the extrusion of a polymer through a spinneret either in solution or as a melt to form a fiber.

1.4 There Are Eight Major Classes Of Ingredients Which Are Used In The Manufacture Of Polymers And Man-Made Fibers

The eight major classes of ingredients are presented in Table II-2 along with a discussion of their purpose in the manufacture of products in this industry.

These classes may be divided into two functional groups:

- The first group includes the monomers, catalysts or initiators and carrier fluids which are the basic feed requirements (raw materials) for polymer production.
- Modifiers, plasticizers, chemical additives, dyes and pigments and processing chemicals constitute the second group. These substances are used to alter the physico-chemical properties of the product so that they may be further processed.

The fact that there are two general groups of ingredients should not be construed as implying a two step operation in most cases. For instance, in SIC 2822 carbon black and plasticizers are added to the reaction mixture at the polymerization step, thus producing a "master batched rubber".

1.5 Products Produced By SIC 282 Are Critical In The U.S. Economy

This industry produces materials which are broadly dispersed throughout the U.S. economy and are used in the subsequent production of a variety of items.

1

TABLE II-2

MAJOR CLASSES OF INGREDIENTS USED IN THE MANUFACTURE OF POLYMERS AND MAN-MADE FIBERS

SIC 282

I.	Monomers	--	The building blocks of the resins or elastomers. Some monomers are treated by addition of small amounts of inhibitors to prevent autopolymerization in storage.
II.	Catalysts and Initiators	--	These chemicals are introduced to start the polymerization process and to accelerate the reaction.
III.	Carrier Fluids	--	These fluids may be water or organic solvents added to reduce the viscosity during polymerization and to improve the heat transfer.
IV.	Modifiers	--	Chemicals which are incorporated in the basic polymer chains so as to modify the physical properties (e.g., rigidity or tenacity) of the product.
V.	Plasticizers	--	Chemicals which are mixed with the polymers, but are not chemically incorporated. Their purpose is to make the polymer more pliable.
VI.	Chemical Additives	--	These are materials which are added to the polymer to modify the chemical properties of the product. For example, this may include antioxidants and photodesensitizers.
VII.	Dyes and Pigments	--	These may include organic as well as inorganic compounds. The dyes are dissolved in the polymer while the pigments are physically dispersed in the mass. Their purpose is to mask or impart color to the polymer.
VIII.	Processing Chemicals	--	These chemicals are used to control pH conditions or other physicochemical parameters of the aqueous streams used in both the polymerization and spinning processes.

Source: Foster D. Snell, Inc.

For example, the following table demonstrates the pattern of consumption of one of the industry segments--Plastics and Resins (SIC 2821) for 1970. (Source: Modern Plastics, July 1973, and Foster D. Snell, Inc. estimates).

Table II-3 -- Consumption Of Products Produced In SIC 2821

Market	Present Consumption of Plastics in 1970
Building and construction	24%
Packaging	27
Transportation	10
Electric/electronics	9
Furniture	4
Housewares	5
Appliances	3
Other	18
Total:	100%

In fact, the "other" category demonstrates the wide distribution. This category includes toys, textile and paper treating, agriculture, marine craft, signs, shoes and phonograph records.

Other SIC 282 products are similarly widely dispersed. Indeed the products of SIC 2824 constitute over 90% of all apparel worn in this country.

1.6 Wastes Generated By SIC 282 Establishments Are Generally Produced Directly As A Result Of The Unit Operations

Figure II-1, presents a generalized processing flow diagram. The following steps or unit operations are common to many processes within the industry:

- Monomer(s) storage
- Monomer preparation(1)
- Monomer(s) feeding to the reactor
- Carrier feeding to the reactor(2)
- Catalyst feeding to the reactor
- Reaction
- Monomer(s) recovery
- Carrier recovery(1)
- Catalyst removal or recovery(1)
- Polymer processing.

Waste streams generated by these unit operations include:

- Inhibitor removal from monomer preparation
- Still bottoms from monomer and carrier recovery
- Catalyst wastes from catalyst removal or recovery
- Off grade polymer or fiber product from production upsets which may occur at the reaction or polymer steps
- Sludges from on-site wastewater treatment facilities.

In addition to these waste streams, others are generated by spillage in warehousing or storage areas, the action of particulate emission control equipment, lubricating oil changes and the discarding of defective packaging materials.

Notes: (1) Where required.
(2) Except for bulk processes.

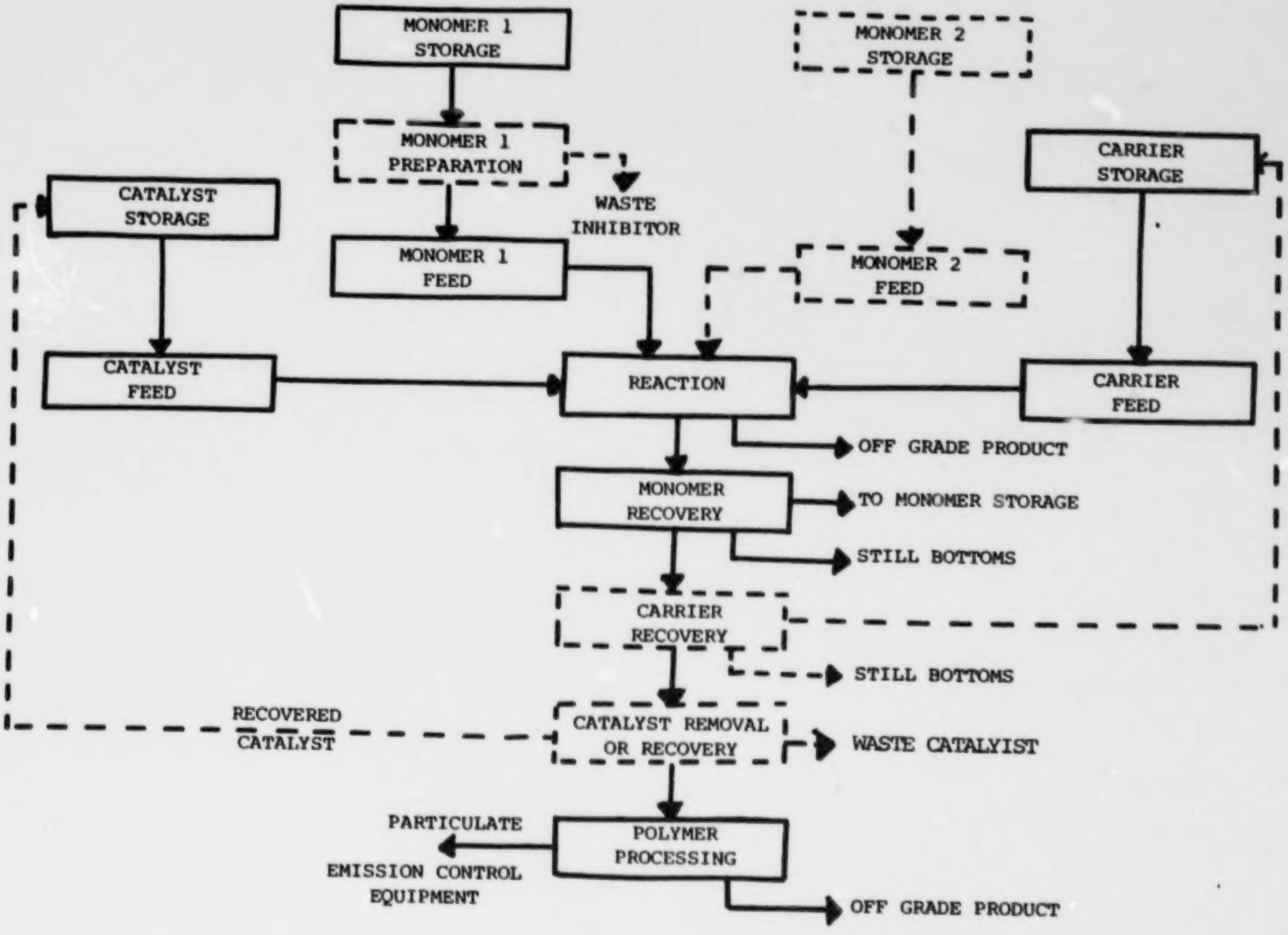
MONOMER 1 STORAGE
MONOMER 2 STORAGE
MONOMER 1 PREPARATION
CARRIER STORAGE
CATALYST STORAGE
WASTE INHIBITOR
MONOMER 1 FEED
MONOMER 2 FEED
CATALYST FEED
REACTION
CARRIER FEED
OFF GRADE PRODUCT
MONOMER RECOVERY
TO MONOMER STORAGE
STILL BOTTOMS
CARRIER RECOVERY
STILL BOTTOMS
RECOVERED CATALYST
CATALYST REMOVAL OR RECOVERY
WASTE CATALYIST
PARTICULATE
POLYMER PROCESSING
EMISSION CONTROL EQUIPMENT
OFF GRADE PRODUCT

FIGURE II-1. GENERALIZED PROCESSING FLOW DIAGRAM

Note: Unit operations represented by dotted lines do not appear in all of the processes. Differences between process types are discussed in the text.

Source: Foster, D. Snell, Inc.

1.7 A Significant Portion Of The Wastes Generated By SIC 282 May Be Potentially Hazardous

Inhibitor wastes generated by monomer preparation, still bottoms from monomer and carrier recovery and off grade polymer may in certain cases contain organic materials which may be toxic or highly flammable.

Catalyst wastes from catalyst removal or recovery and sludges from on-site wastewater treatment facilities may contain metal ions such as tin, zinc, cadmium and nickel. These metals are considered to be toxic.

The potentially hazardous nature of these wastes varies with the product. Individual waste streams generated by the processes studied are characterized, on a case by case basis, in terms of their potential hazard in Section 4 of this chapter.

2. CHARACTERIZATION OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY

Tables D-1 through D-4 in Appendix D present a detailed definition of each of the four industry segments of SIC 282.

Table II-4 lists the principal products of SIC 282 in the order of decreasing importance in terms of estimated 1974 production volumes. The following conclusions may be drawn from the table:

- The total 1974 estimate of production volumes for SIC 282 was on the order of 30,000 KKKg.
- The greatest production in terms of weight was in SIC 2821 and 2824 with these industries accounting for approximately 85% of all production in SIC 282.
- SICs 2822 and 2823 only accounted for approximately 15% of the production in the plastic materials and synthetics industry.
- There are twenty-one important polymer types or classes produced by SIC 282 establishments. The first eight, polyesters, polyamides, polyethylene, vinyl resins, styrenes, polypropylene, acrylics and SBR account for over 85% of the total production by weight in SIC 282. In fact the first three account for over 50% of the production.

The remainder of this section details the industry structure by four digit SIC for each of the segments of the plastic materials and synthetics industry as follows:

- Sub-Section 2.1 -- SIC 2821, Plastics Materials and Resins.
- Sub-Section 2.2 -- SIC 2822, Synthetic Rubber.
- Sub-Section 2.3 -- SIC 2823, Cellulosic Man-Made Fibers.
- Sub-Section 2.4 -- SIC 2824, Organic Fibers, Non-Cellulosic.

TABLE II-4

ESTIMATED PRODUCT VOLUME OF PRINCIPAL PRODUCTS OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282 (1974)

Product	Total Production	-------Production by SIC - KKKg/yr.-----			
		2821	2822	2823	2824
Polyesters	6,855 (1)	451			6,440
Polyamides	4,727	52			4,675
Polyethylene	4,018	4,018			
Vinyl Resins	2,277	2,277			
Styrene Resins	2,284	2,284			
Polypropylene	2,196 (1)	1,026			1,170
SBR	2,117	301	426		1,390
SBR	2,116		2,116		
Cellulosics	626	87		539	
Phenolics	610	610			
Polyurethanes	538	53	485		
Polybutadiene	477		477		
Amino Resins	377	377			
Alkyds	317	317			
Neoprene	177		177		
Butyl Rubber	166		166		
EPM-EPDM	166		166		
Coumarone-Indene	148	148			
Isoprene	142		142		
Epoxy	113	113			
Silicone	27		27		
	30,474	12,078	4,182	539	13,675

SBR = Styrene-Butadiene Rubber.

EPM-EPDM = Ethylene-Propylene Rubbers. EPM are copolymer and EPDM are terpolymers.

Note: (1) The quantity of production listed under SIC 2821 and SIC 2824 may not be additive due to possible transfers from 2821 to 2824.

Source: Foster D. Snell, Inc.

2.1 Structure Of The Plastics Materials And Resins Industry, SIC 2821

For this industry in 1972, value added by manufacturer was $2,160.5 million according to the 1973 Census of Manufacturers, while value of shipments was $4,478.2 million. There were over 54,000 employees working in SIC 2821 in 1972.

The products of this industry (i.e., polyethylene, polyvinyl chloride, etc.) are used throughout the U.S. economy with over 50% of production going into building and construction and packaging materials.

There are literally thousands of resin types produced by this industry. For the purposes of this study, the report focuses on those resins which are responsible for over 95% of the industrial production. These resins are:

- High and low density polyethylene
- Polyvinyl chloride
- Polyvinyl acetate
- ABS-SAN
- Polystyrene
- Polypropylene
- Phenolics and other tar acid resins
- Polyesters
- Amino resins
- Alkyds
- Acrylics
- Coumarone-Indene and petroleum resins
- Polyurethanes
- Cellulosic
- Epoxy
- Polyamides.

Appendix A presents the detailed methodology used in developing the data presented in the tables for this industry.

2.1.1 Geographic Distribution Of Plants And Their Capacities In SIC 2821

Table II-5 presents the geographic distribution of production units and their capacities for this industry segment.

- Our survey has found that there are approximately 816 production units within SIC 2821. This value differs from the value of 323 establishments given in the 1972 Census of Manufacturers. It is felt that this discrepancy is due to the fact that while the study team is counting the number of sites where a particular resin is manufactured, the Census is, in reality, counting the number of plant complexes where several resins may be produced. For the purposes of the report, the study team's method of counting is more applicable because it provides a more realistic overview of the geographic distribution.
- The highest concentration of production units and capacity is in the Atlantic states including New Jersey, New York and Pennsylvania, the Gulf Coast states such as Louisianna and Texas plus the states of Ohio, Michigan, Kentucky and California. In general, these are the locations of production sites for petroleum based chemicals required by the industry for its production processes.

Of the resins produced in SIC 2821, the greatest capacity exists for polyethylene manufacture with a total of 4,305 KKKg/yr., followed by polyvinyl chloride at 2,982 KKKg/yr. and polystyrene with a capacity for 1,935 KKKg/yr. Lower capacity exists for such products as epoxy resins at 136 KKKg/yr. and for polyamides at about 52 KKKg/yr.

TABLE II-5 (1)

GEOGRAPHIC DISTRIBUTION OF PRODUCTION UNITS AND CAPACITIES IN SIC 2821, PLASTICS MATERIALS AND RESINS

		High Density Polyethylene		Low Density Polyethylene	
		Number Production Units	Capacity KKKg/yr	Number Production Units	Capacity KKKg/yr
IV	Alabama				
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California			1	55
VIII	Colorado				
I	Connecticut				
III	Delaware				
IV	Florida				
IV	Georgia				
IX	Hawaii				
X	Idaho				
V	Illinois			2	339
V	Indiana			1	110
VII	Iowa	1	77	1	145
VII	Kansas				
IV	Kentucky				
VI	Louisiana	2	260	3	537
I	Maine				
III	Maryland				
I	Massachusetts				
V	Michigan				
V	Minnesota				
IV	Mississippi				
VII	Missouri				
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey				
VI	New Mexico				
II	New York				
IV	North Carolina				
VIII	North Dakota				
V	Ohio				
VI	Oklahoma				
X	Oregon				
III	Pennsylvania				
I	Rhode Island				
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas	10	990	12	1792
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington				
III	West Virginia				
V	Wisconsin				
VIII	Wyoming				
	TOTAL	13	1327	20	2978
	Region I				
	II				
	III				
	IV				
	V			3	449
	VI	12	1250	15	2329
	VII	1	77	1	145
	VIII				
	IX			1	55
	X				

Source: Foster D. Snell, Inc. analysis of data from:
(a) Systems Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.
(b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975
(c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.
(d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

TABLE II-5 (2)

		PVC		PVAC		PVA	
		Number Production Units	Capacity KKKg/yr	Number Production Units	Capacity KKKg/yr	Number Production Units	Capacity KKKg/yr
IV	Alabama			1	4		
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	2	123	5	13		
VIII	Colorado						
I	Connecticut						
III	Delaware	2	250				
IV	Florida	1	55	1	2		
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois	2	140	3	18		
V	Indiana						
VII	Iowa						
VII	Kansas			1	2		
IV	Kentucky	2	125	3	18	1	14
VI	Louisiana	4	357				
I	Maine						
III	Maryland	1	91	1	1		
I	Massachusetts	4	242	4	29	2	68
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	4	300	5	34		
VI	New Mexico						
II	New York	2	135	1	4		
IV	North Carolina			1	2		
VIII	North Dakota						
V	Ohio	4	353	2	12		
VI	Oklahoma	1	100				
X	Oregon						
III	Pennsylvania	1	91				
I	Rhode Island	1	50				
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	3	425			1	46
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington			1	2		
III	West Virginia	3	145	2	8		
V	Wisconsin						
	TOTAL	37	2982	31	149	4	128
Region	I	5	292	4	29	2	68
	II	6	435	6	38		
	III	7	577	3	9		
	IV	3	180	6	26	1	14
	V	6	493	5	30		
	VI	8	882			1	46
	VII			1	2		
	VIII						
	IX	2	123	5	13		
	X			1	2		

PVC = Polyvinyl Chloride PVAC = Polyvinyl Acetate PVA = Polyvinyl Alcohol

Source: Foster D. Snell, Inc. analysis of data from:

(a) Systems Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.

(b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975

(c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.

(d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

		ABS-SAN		Polystyrene	
		Number Production Units	Capacity KKKg/yr	Number Production Units	Capacity KKKg/yr
IV	Alabama				
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California	1	9	6	315
VIII	Colorado				
I	Connecticut	1	30	2	125
III	Delaware				
IV	Florida				
IV	Georgia				
IX	Hawaii				
X	Idaho				
V	Illinois	2	114	5	360
V	Indiana				
VII	Iowa				
VII	Kansas				
IV	Kentucky	1	14		
VI	Louisiana	2	91		
I	Maine				
III	Maryland				
I	Massachusetts			8	395
V	Michigan	1	48	1	80
V	Minnesota				
IV	Mississippi				
VII	Missouri			1	80
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey	1	16		
VI	New Mexico				
II	New York				
IV	North Carolina			1	15
VIII	North Dakota				
V	Ohio	1	123	6	475
VI	Oklahoma				
X	Oregon				
III	Pennsylvania				
I	Rhode Island				
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas			1	90
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington				
III	West Virginia	1	119		
V	Wisconsin				
VIII	Wyoming				
	TOTAL	11	564	33	1935
	Region I	1	30	10	520
	II	1	16		
	III	1	119		
	IV	1	14	1	15
	V	4	285	12	915
	VI	2	91	1	90
	VII			1	80
	VIII				
	IX	1	9	6	315
	X				

ABS-SAN = Acrylonitrile-Butadiene-Styrene Resins and Styrene-Acrylonitrile

Source: Foster D. Snell, Inc. analysis of data from:

(a) Systems Analysis of Air Pollutant Emissions from the Chemical Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.

(b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975

(c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.

(d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

TABLE II-5 (4)

		Polypropylene		Phenolics and Other Tar Acid Resins	
		Production Units	Capacity KKKg/yr	Production Units	Capacity KKKg/yr
IV	Alabama			1	12
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California			8	55
VIII	Colorado				
I	Connecticut			1	4
III	Delaware	1	115		
IV	Florida			1	4
IV	Georgia				
IX	Hawaii				
X	Idaho				
V	Illinois			1	4
V	Indiana				
VII	Iowa				
VII	Kansas			1	12
IV	Kentucky				
VI	Louisiana	1	315		
I	Maine				
III	Maryland				
I	Massachusetts			2	32
V	Michigan			1	12
V	Minnesota				
IV	Mississippi				
VII	Missouri				
VIII	Montana			1	2
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey	1	125	5	50
VI	New Mexico				
II	New York			4	102
IV	North Carolina			4	29
VIII	North Dakota				
V	Ohio			3	117
VI	Oklahoma				
X	Oregon			5	38
III	Pennsylvania				
I	Rhode Island				
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas	7	585	4	49
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington			2	18
III	West Virginia	1	75		
V	Wisconsin			2	36
VIII	Wyoming				
	TOTAL	11	1215	46	576
	Region I			3	36
	II	1	125	9	152
	III	2	190		
	IV			6	45
	V			7	169
	VI	8	900	4	49
	VII			1	12
	VIII			1	2
	IX			8	55
	X			7	56

Source: Foster D. Snell, Inc. analysis of data from:

(a) Systems Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.

(b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975

(c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.

(d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

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TABLE II-5 (5)

		Polyesters		Amino Resins[1]	Alkyds[1]
		Number Production Units	Capacity KKKg/yr	Number Production Units	Number Production Units
IV	Alabama			3	1
X	Alaska				
IX	Arizona				
VI	Arkansas	1	23	2	
IX	California	18	140	13	30
VIII	Colorado				2
I	Connecticut	1	11	1	
III	Delaware	1	11	2	1
IV	Florida	6	87	2	4
IV	Georgia			3	3
IX	Hawaii				
X	Idaho				
V	Illinois	3	7	10	23
V	Indiana	2	21		1
VII	Iowa				2
VII	Kansas				
IV	Kentucky	1	5	2	5
VI	Louisiana	1	10	1	
I	Maine			1	
III	Maryland			1	5
I	Massachusetts			5	5
V	Michigan	6	57	3	6
V	Minnesota				2
IV	Mississippi			1	
VII	Missouri	3	42	1	7
VIII	Montana			1	
VII	Nebraska				
IX	Nevada			2	
I	New Hampshire			2	
II	New Jersey	5	44	18	26
VI	New Mexico				
II	New York	3	15	5	9
IV	North Carolina	2	15	14	
VIII	North Dakota				
V	Ohio	11	68	12	13
VI	Oklahoma	1	14		3
X	Oregon	1	2	12	2
III	Pennsylvania	5	36	11	13
I	Rhode Island			7	
IV	South Carolina	2	26	5	1
VIII	South Dakota				
IV	Tennessee	3	35	1	1
VI	Texas	3	27	8	10
VIII	Utah				1
I	Vermont				
III	Virginia			3	
X	Washington	1	13	6	
III	West Virginia				
V	Wisconsin	1	16	8	3
VIII	Wyoming				
	TOTAL	81	725	164	179
	Region I	1	11	16	5
	II	8	59	23	35
	III	6	47	17	19
	IV	14	168	31	15
	V	23	169	33	51
	VI	6	74	11	10
	VII	3	42	1	9
	VIII			1	3
	IX	18	140	13	30
	X	2	15	18	2

---

(1) Capacities not available for these resins.

Source: Foster D. Snell, Inc. analysis of data from:

- (a) Systems Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.
- (b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975
- (c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.
- (d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

TABLE II-5 (6)

		Acrylics		Coumarone-Indene(1) and Petroleum Resins	Polyurethanes(1)
		Number Production Units	Capacity KKKg/yr	Number Production Units	Number Production Units
IV	Alabama			1	1
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California			2	28
VIII	Colorado				1
I	Connecticut				1
III	Delaware				2
IV	Florida				
IV	Georgia				1
IX	Hawaii				
X	Idaho				
V	Illinois			3	16
V	Indiana				1
VII	Iowa				2
VII	Kansas				
IV	Kentucky	1	2		1
VI	Louisiana	1	91	2	
I	Maine				
III	Maryland				3
I	Massachusetts			1	9
V	Michigan				4
V	Minnesota				2
IV	Mississippi			3	
VII	Missouri				4
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				1
II	New Jersey			1	13
VI	New Mexico				
II	New York				7
IV	North Carolina				
VIII	North Dakota				
V	Ohio				12
VI	Oklahoma				
X	Oregon				2
III	Pennsylvania			4	11
I	Rhode Island				1
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas	4	337	2	5
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington				2
III	West Virginia	1	32	1	2
V	Wisconsin				3
VIII	Wyoming				
	TOTAL	7	462	20	135
	Region I			1	12
	II			1	20
	III	1	32	5	18
	IV	1	2	4	3
	V			3	38
	VI	5	428	4	5
	VII				6
	VIII				1
	IX			2	28
	X				4

---

(1) Capacities not available for these resins.

Source: Foster D. Snell, Inc. analysis of data from:

(a) Systems Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.

(b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975

(c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.

(d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

		Cellulosic Resins (1)	Epoxy Resins		Polyamides	
		Number Production Units	Number Production Units	Capacity KKKg/yr	Number Production Units	Capacity KKKg/yr
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California					
VIII	Colorado					
I	Connecticut					
III	Delaware					
IV	Florida				1	11
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois					
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky		1	16	2	8
VI	Louisiana					
I	Maine					
III	Maryland	1				
I	Massachusetts	1	1	6	1	n.a.
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire				1	2
II	New Jersey	5	3	45		
VI	New Mexico					
II	New York					
IV	North Carolina					
VIII	North Dakota					
V	Ohio		1	6		
VI	Oklahoma					
X	Oregon					
III	Pennsylvania				1	1
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee	1			1	1
VI	Texas		2	63	1	n.a.
VIII	Utah					
I	Vermont					
III	Virginia				1	7
X	Washington					
III	West Virginia				1	32
V	Wisconsin					
VIII	Wyoming					
	TOTAL	8	8	136	10	62+
	Region I	1	1	6	2	2+
	II	5	3	45		
	III	1			3	40
	IV	1	1	16	4	20
	V		1	6		
	VI		2	63	1	n.a.
	VII					
	VIII					
	IX					
	X					

---

(1) Capacities not available for these resins.

Source Foster D. Snell, Inc. analysis of data from

(a) Systems Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology Series EPA 650/2-74-106, October, 1974.

(b) "Supply Status", Modern Plastics, Vol. 52, No. 1, January, 1975

(c) 1974 Final Monthly Statistical Report Plastic & Resin Materials, SPI etc., SPI Committee on Resin Statistics as compiled by Ernst & Ernst.

(d) "Plastics & Resins", Chemical Economic Handbook, Stanford Research Institute

2.1.2 Geographic Distribution Of Employment

Table II-6 presents the estimated 1974 geographic distribution of employment as a function of the number of production units. Information is presented as an aggregate for the entire SIC 2821 since employement figures related to each of the resins was not available.

- There was a total of 56,450 employees estimated to be working in the industry on an average of approximately 70 employees per production unit.
- Employment was concentrated in the same manner as production units and capacity discussed under 2.1.1.

The following data provides an estimate of production unit size distribution by employment on a national basis for SIC 2821 as a whole.

Table II-7 -- Production Unit Size Distribution By Employment, SIC 2821 (National Basis)

Number of Production Units	1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1,000-2,499	2,500 or more
816	38	38	76	232	139	167	66	35	20	5

From the above information, it can be seen that the greatest number of production units (232) have between 20-49 employees and account for 28% of the industry. Most of the production units (66%) are in the size range between 20-249 employees. Only 3% of the production units have 1,000 employees or more. Nineteen percent have fewer than 20 employees.

TABLE II-8

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF PLANTS AND EMPLOYMENT IN SIC 2821

		Total Number of Production Units	Employment
IV	Alabama	8	50
X	Alaska		
IX	Arizona		
VI	Arkansas	3	100
IX	California	114	2200
VIII	Colorado	3	50
I	Connecticut	7	1800
III	Delaware	9	800
IV	Florida	16	200
IV	Georgia	7	200
IX	Hawaii	7	N.A.
X	Idaho		
V	Illinois	70	4500
V	Indiana	8	1800
VII	Iowa	6	350
VII	Kansas	2	350
IV	Kentucky	10	2550
VI	Louisiana	17	1800
I	Maine	4	
III	Maryland	12	200
I	Massachusetts	43	5900
V	Michigan	22	2550
V	Minnesota	7	750
IV	Mississippi	4	50
VII	Missouri	16	200
VIII	Montana	2	N.A
VII	Nebraska		
IX	Nevada		
I	New Hampshire	4	200
II	New Jersey	87	5300
VI	New Mexico		
II	New York	31	2000
IV	North Carolina	22	350
VIII	North Dakota		
V	Ohio	65	4500
VI	Oklahoma	2	150
X	Oregon	22	100
III	Pennsylvania	46	5900
I	Rhode Island	9	100
IV	South Carolina	8	200
VIII	South Dakota		
IV	Tennessee	7	1800
VI	Texas	73	4250
VIII	Utah	1	N.A.
I	Vermont		
III	Virginia	4	100
X	Washington	12	100
III	West Virginia	12	4250
V	Wisconsin	17	750
VIII	Wyoming		
	TOTAL	816	56,450
	Region I	64	8000
	II	48	7300
	III	83	11,250
	IV	92	5400
	V	186	14,850
	VI	95	6300
	VII	24	900
	VIII	6	50
	IX	114	2200
	X	34	200

Source: Snell update of data from the 1972 Census of Manufacturers, U.S. Department of Commerce, Publication MC-72(2)-28B.

2.1.3 Distribution Of Plant Age

Distribution of plant age is not provided for SIC 2821 due to the inavailability of data. Most of the production units, however, were first constructed after the Second World War with many of the major ones being built in the late 1950's and early 1960's.

2.1.4 Geographic Distribution Of Production Volumes

Table II-8 is a summary of the geographic distribution of production volume by production unit for SIC 2821 as an aggregate for 1974.

Table II-9 presents the geographic distribution of the estimated production volume of the sixteen major SIC 2821 resins listed in Section 2.1.

From these tables, the following conclusions can be drawn:

- Over 12,000 KKKg of resins were estimated to have been produced in 1974 by SIC 2821 pro duction units.
- The general concentration of production units and production was identical with that for capacities as shown in Table II-6.

For the entire SIC 2921 industry segment an average of approximately 15 KKKg of material was produced by each production unit in 1974. This value reflects the fact that there are many units producing only a small amount of resin. This is particularly valid for the phenolics, alkyd and polyurethane resins.

On the average, over 80% of the production capacity for SIC 2821 was utilized in 1974. For example, of the high volume resins:

- Polyethylene was being produced at 93% of capacity
- Polystyrene was at 95% of capacity
- Polypropylene at about 84% of capacity
- Polyvinyl chloride was being produced at 75% of capacity.

TABLE II-8

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF TOTAL PRODUCTION UNITS AND TOTAL PRODUCTION, SIC 2821

		Total Number of Production Units	Total Production (KKKg/yr)
IV	Alabama	8	29.4
X	Alaska		
IX	Arizona		
VI	Arkansas	3	18.0
IX	California	114	696.9
VIII	Colorado	3	4.4
I	Connecticut	7	154.4
III	Delaware	9	296.8
IV	Florida	16	117.0
IV	Georgia	7	12.4
IX	Hawaii		
X	Idaho		
V	Illinois	70	945.2
V	Indiana	8	119.4
VII	Iowa	6	212.8
VII	Kansas	2	13.0
IV	Kentucky	20	149.4
VI	Louisiana	17	1,430.0
I	Maine	1	2.0
III	Maryland	12	91.2
I	Massachusetts	43	665.5
V	Michigan	22	178.6
V	Minnesota	4	4.8
IV	Mississippi	4	24.0
VII	Missouri	16	115.5
VIII	Montana	2	4.0
VII	Nebraska		
IX	Nevada		
I	New Hampshire	4	7.4
II	New Jersey	87	610.1
VI	New Mexico		
II	New York	31	246.7
IV	North Carolina	22	86.0
VIII	North Dakota		
V	Ohio	65	1,033.7
VI	Oklahoma	2	82.0
X	Oregon	22	73.8
III	Pennsylvania	46	173.3
I	Rhode Island	9	53.4
IV	South Carolina	8	29.0
VIII	South Dakota		
IV	Tennessee	7	36.0
VI	Texas	73	3,916.0
VIII	Utah	1	2.0
I	Vermont		
III	Virginia	4	13.0
X	Washington	12	40.8
III	West Virginia	12	317.8
V	Wisconsin	17	72.2
VIII	Wyoming		
	TOTAL	816	12.078
	Region I	64	881.7
	II	118	856.8
	III	83	892.1
	IV	92	483.2
	V	186	2,353.9
	VI	95	5,447.0
	VII	24	341.4
	VIII	6	10.4
	IX	114	696.9
	X	34	114.6

Source: Foster D. Snell, Inc.

TABLE II-9 (1)

GEOGRAPHIC DISTRIBUTION OF PRODUCTION IN SIC 2821. PLASTIC MATERIALS AND RESINS

		Production -- KKKg/yr				
		HDPE (1)	LDPE (1)	PVC (1)	PVAC (2)	PVA (1)
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California		50	91		
VIII	Colorado					
I	Connecticut					
III	Delaware			186		
IV	Florida			41		
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois		310	104		
V	Indiana		100			
VII	Iowa	75	133			
VII	Kansas					
IV	Kentucky			93		7
VI	Louisiana	254	491	265		
I	Maine					
III	Maryland			68		
I	Massachusetts			180		35
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey			223		
VI	New Mexico					
II	New York			100		
IV	North Carolina					
VIII	North Dakota					
V	Ohio			260		
VI	Oklahoma			74		
X	Oregon					
III	Pennsylvania			68		
I	Rhode Island			37		
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	965	1,640	315		23
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia			107		
V	Wisconsin					
VIII	Wyoming					
	TOTAL	1,294	2,724	2,212		65
	Region I			217		35
	II			323		
	III			429		
	IV			134		7
	V		410	364		
	VI	1,219	2,131	654		23
	VII	75	133			
	VIII					
	IX		50	91		
	X					

HDPE = High Density Polyethylene
LDPE = Low Density Polyethylene
PVC = Polyvinyl Chloride
PVAC = Polyvinyl Acetate
PVA = Polyvinyl Alcohol

Notes:

(1) Production figures based on data from the 1974 Final Monthly Statistical Report, Plastic & Resin Materials, SPI Committee on Resin Statistics as compiled by Ernst & Ernst, March 21, 1975, and pro rated according to capacity.

(2) Production data is not comparable to that of other resins as it is expressed in terms of the monomer.

		Production -- KKKg/yr			
		ABS-SAN(1)	Polystyrene(1)	Polypropylene(1)	Phenolics and Other Tar Acid Resins (1)
IV	Alabama				13
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California	7	300		58
VIII	Colorado				
I	Connecticut	23	119		4
III	Delaware			97	
IV	Florida				4
IV	Georgia				
IX	Hawaii				
X	Idaho				
V	Illinois	89	343		4
V	Indiana				
VII	Iowa				
VII	Kansas				13
IV	Kentucky	11			
VI	Louisiana	72		266	
I	Maine				
III	Maryland				
I	Massachusetts		376		34
V	Michigan	37	76		13
V	Minnesota				
IV	Mississippi				
VII	Missouri		76		
VIII	Montana				2
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey	12		105	53
VI	New Mexico				
II	New York				108
IV	North Carolina		14		31
VIII	North Dakota				
V	Ohio	96	454		124
VI	Oklahoma				
X	Oregon				40
III	Pennsylvania				
I	Rhode Island				
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas		86	494	52
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington				19
III	West Virginia	93		63	
V	Wisconsin				38
VIII	Wyoming				
	TOTAL	440	1,844	1,026	610
Region	I	23	495		38
	II	12		106	161
	III	93		160	
	IV	11	14		48
	V	222	873		179
	VI	72	86	760	52
	VII		76		13
	VIII				2
	IX	7	300		58
	X				59

ABS-SAN = Acrylonitrile-Butadiene-Styrene Resins and Styrene-Acrylonitrile

Notes:

(1) Production figures based on data from the 1974 Final Monthly Statistical Report, Plastic & Resin Materials, SPI Committee on Resin Statistics as compiled by Ernst & Ernst, March 21, 1975, and pro rated according to capacity.

TABLE II-9 (3)

		Production -- KKKg/yr				
		Polyesters (1)	Amino Resins (2)	Alkyds (2)	Acrylics (3)	Coumarone-Indene and Petroleum Resins (2)
IV	Alabama		7	2		7
X	Alaska					
IX	Arizona					
VI	Arkansas	13	5			
IX	California	82	31	52		15
VIII	Colorado			4		
I	Connecticut	6	2			
III	Delaware	6	5	2		
IV	Florida	51	5	7		
IV	Georgia		7	5		
IX	Hawaii					
X	Idaho					
V	Illinois	4	23	40		22
V	Indiana	12		7		
VII	Iowa			4		
VII	Kansas					
IV	Kentucky	3	5	9	1	
VI	Louisiana	6	2		59	15
I	Maine		2			
III	Maryland		2	9		
I	Massachusetts		5	9		7
V	Michigan	33	7	11		
V	Minnesota			4		
IV	Mississippi		2			22
VII	Missouri	24	2	12		
VIII	Montana		2			
VII	Nebraska					
IX	Nevada					
I	New Hampshire		5			
II	New Jersey	25	42	46		7
VI	New Mexico					
II	New York	8	12	16		
IV	North Carolina	8	33			
VIII	North Dakota					
V	Ohio	39	28	23		
VI	Oklahoma	8				
X	Oregon	1	28	4		
III	Pennsylvania	20	26	23		31
I	Rhode Island		16			
IV	South Carolina	15	12	2		
VIII	South Dakota					
IV	Tennessee	20	2	2		
VI	Texas	15	19	17	220	15
VIII	Utah			2		
I	Vermont					
III	Virginia		7			
X	Washington	7	14			
III	West Virginia				21	7
V	Wisconsin	9	19	5		
VIII	Wyoming					
	TOTAL	415	377	317	301	148
Region	I	6	30	9		7
	II	33	54	62		7
	III	26	40	34	21	38
	IV	97	73	27	1	29
	V	97	77	90		22
	VI	42	26	17	279	30
	VII	24	2	16		
	VIII		2	6		
	IX	82	31	52		15
	X	8	42	4		

Notes:

(1) Production figures based on data from the 1974 Final Monthly Statistical Report, Plastic & Resin Materials, SPI Committee on Resin Statistics as compiled by Ernst & Ernst, March 21, 1975, and pro rated according to capacity.

(2) Production figures based on data from System Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Technology series EPA 650/2-74-106, October, 1974, and pro rated according to production unit distribution.

(3) Data from above but pro rated by capacity.

TABLE II-9 (4)

		Production -- KKKg/yr			
		Poly-urethanes (1)	Cellulosic Resins (1)	Epoxy Resins (2)	Polyamides (2)
IV	Alabama	0.4			
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California	10.9			
VIII	Colorado	0.4			
I	Connecticut	0.4			
III	Delaware	0.8			
IV	Florida				9
IV	Georgia	0.4			
IX	Hawaii				
X	Idaho				
V	Illinois	6.2			
V	Indiana	0.4			
VII	Iowa	0.8			
VII	Kansas				
IV	Kentucky	0.4		13	7
VI	Louisiana				
I	Maine				
III	Maryland	1.2	11		
I	Massachusetts	3.5	11	5	n.a.
V	Michigan	1.6			
V	Minnesota	0.8			
IV	Mississippi				
VII	Missouri	1.6			
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire	0.4			2
II	New Jersey	5.1	54	37	
VI	New Mexico				
II	New York	2.7			
IV	North Carolina				
VIII	North Dakota				
V	Ohio	4.7		5	
VI	Oklahoma				
X	Oregon	0.8			
III	Pennsylvania	4.3			1
I	Rhode Island	0.4			
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee		11		1
VI	Texas	2.0		53	n.a.
VIII	Utah				
I	Vermont				
III	Virginia				6
X	Washington	0.8			
III	West Virginia	0.8			26
V	Wisconsin	1.2			
VIII	Wyoming				
	TOTAL	53	87	113	52+
Region	I	47	11	5	2+
	II	7.8	54	37	
	III	7.1	11		33
	IV	1.2	11	13	17
	V	14.9		5	
	VI	2.0		53	n.a.
	VII	2.4			
	VIII	0.4			
	IX	10.9			
	X	1.6			

Notes:

(1) Production figures based on data from System Analysis of Air Pollutant Emissions from the Chemical/Plastics Industry, U.S. Environmental Protection Agency, Environmental Protection Technology series EPA 650/2-74-106, October, 1974, and pro rated according to production unit distribution.

(2) Production figures based on data from the 1974 Final Monthly Statistical Report, Plastic & Resin Materials, SPI Committee on Resin Statistics as compiled by Ernst & Ernst, March 21, 1975, and pro rated according to capacity.

For typical lower volume resins, the following are estimates of capacity utilization for 1974:

- ABS/SAN -- 78%
- Polyesters -- 57%
- Acrylics -- 65%
- Epoxy -- 83%

2.2 Structure Of The Synthetic Rubber (Vulcanizable Elastomers) Industry, SIC 2822

For this industry in 1972, value added by manufacturers was $491.7 million according to the 1972 Census of Manufacturers, while value of shipments was $1,089.4. There were over 11,000 employees working in SIC 2822 in 1972.

The products of this industry are principally used in five segments of the U.S. economy: new tire production, tire retreading, molded rubber goods, footwear and adhesives. In 1973 about 65% of synthetic rubber production went into the production of new tires.

There are approximately 50 different types or classes of synthetic rubber or vulcanizable elastomers. Of these 50, nine are most important on a weight of production basis. These nine synthetic rubbers are, in decreasing order of importance, as follows:

- Styrene-Butadiene Rubber (SBR)
- Polyurethanes
- Polybutadience
- Acrylics
- Neoprene
- Butyl rubber
- Ethylene-propylene co- and ter- polymers (EPM and EPDM)
- Isoprene
- Silicone.

In general, this report focuses on the above nine elastomers since they represent over 95% of SIC 2822's production.

Appendix A presents the detailed methodology used in developing the data presented in the tables for this industry.

2.2.1 Geographic Distribution Of Plants And Production In SIC 2822

Table II-10 presents a summary of the geographic distribution of production units and their estimated 1974 production for this industry segment as an aggregate.

Table II-11 presents the geographic distribution of production units and their estimated 1974 production on a product by product basis.

- Our survey has found that there are approximately 120 production units within SIC 2822.
- The synthetic rubber industry is very heavily concentrated in the Gulf Coast area in such states as Texas and Louisianna, with a smaller grouping in Ohio and Kentucky and minor installations to Connecticut and Tennessee.

Of all the rubbers produced by SIC 2822, the greatest production in 1974 was of SBR type rubber and is estimated to be 2,116 KKKg. This value was on the order of almost four times the production for these next highest synthetic rubbers produced--acrylates, polyurethane and polybutadiene.

2.2.2 Geographic Distribution Of Employment

Table II-12 presents the estimated 1974 geographic distribution of employment. Information is presented as an aggregate for the entire SIC 2822 since employment figures related to each of the rubbers is not available.

- There was a total of about 17,000 employees estimated to be working in the industry.
- Employment was concentrated in the Gulf Coast (Texas and Louisianna) area with a smaller but sizeable grouping in the Ohio/Kentucky area.

The distribution of employment reflects the location of the plants near their suppliers of monomers (Gulf Coast) or their location near the major tire plants where about 65% of the production from SIC 2822 is used.

TABLE II-10

SUMMARY OF GEOGRAPHIC DISTRIBUTION OF PRODUCTION UNITS AND ESTIMATED 1974 PRODUCTION, SIC 2822

		Number of Production Units	Production (KKKg/yr)
IV	Alabama	1	0.05
X	Alaska		
IX	Arizona		
VI	Arkansas		
IX	California	5	40.5(1)
VIII	Colorado		
I	Connecticut	7	111.0(1)
III	Delaware	1	20.0
IV	Florida		
IV	Georgia	3	30.0
IX	Hawaii		
X	Idaho		
V	Illinois	5	294.5(1)
V	Indiana		
VII	Iowa		
VII	Kansas		
IV	Kentucky	6	347.7
VI	Louisiana	15	923.8
I	Maine		
III	Maryland		
I	Massachusetts	4	20.0(1)
V	Michigan	4	69.3
V	Minnesota	1	0.05
IV	Mississippi	1	4.5
VII	Missouri		
VIII	Montana		
VII	Nebraska		
IX	Nevada		
I	New Hampshire		
II	New Jersey	7	71.0(2)
VI	New Mexico		
II	New York	3	4.1(1)
IV	North Carolina	2	24.0
VIII	North Dakota		
V	Ohio	14	770.2
VI	Oklahoma		
X	Oregon		
III	Pennsylvania	1	20.0
I	Rhode Island		
IV	South Carolina		
VIII	South Dakota		
IV	Tennessee	2	60.0
VI	Texas	32	2130.2
VIII	Utah		
I	Vermont		
III	Virginia		
X	Washington		
III	West Virginia	6	452.6
V	Wisconsin		
VIII	Wyoming		
	TOTAL	120	5393.5
	Region I	12	131.0
	II	8	75.1
	III	9	492.6
	IV	15	466.3
	V	24	1134.1
	VI	50	3054.0
	VII		
	VIII		
	IX	3	40.5
	X		

Notes:

(1) Production figures for one unit are not available.

(2) Production figures for two units are not available.

Source: Foster D. Snell, Inc.

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF SYNTHETIC RUBBER PRODUCTION

		Acrylates		Acrylic Rubbers		Acrylonitrile Butadiene Rubbers	
		No. of Plants[1]	Production KKKg/yr	No. of Plants[1]	Production KKKg/yr	No. of Plants[1]	Production KKKg/yr
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut			1	N.A.[2]		
III	Delaware						
IV	Florida						
IV	Georgia			1	N.A.		
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky					2	18.2
VI	Louisiana	1	90.8			2	65
I	Maine						
III	Maryland						
I	Massachusetts			1	N.A.	1	5
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey			1	N.A.		
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio			1	1.5	4	67
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	4	336			1	11
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	5	426.8	5	1.5+	10	166.2
Region	I			2	N.A.	1	5
	II			1	N.A.		
	III						
	IV			1	N.A.	2	18.2
	V			1	1.5	4	67
	VI	5	426.8			3	76
	VII						
	VIII						
	IX						
	X						

Notes:

(1) This indicates the number of plants in a given state which produce the given type of rubber. In some instances that type is not the primary product. It may also indicate captive production.

(2) N.A. - not available.

Source: Foster D. Snell, Inc. analysis of "Chemical Profiles" Oil, Paint & Drug Reporter; Ruebensaal's The Rubber Industry Statistical Report

TABLE II-11 (2)

		ABS Resins		Butadiene Styrene Copolymers		Polybutadienes	
		No. of Plants (1)	Production KKKg/yr	No. of Plants (1)	Production KKKg/yr	No. of Plants (1)	Production KKKg/yr
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	1	20	2	16.5		
VIII	Colorado						
I	Connecticut	1	65	3	42		
III	Delaware			1	20		
IV	Florida						
IV	Georgia			2	30		
IX	Hawaii						
X	Idaho						
V	Illinois	2	280	1	7.5	1	7
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky			2	132.5	1	75
VI	Louisiana			3	446.5		
I	Maine						
III	Maryland						
I	Massachusetts			2	15		
V	Michigan	1	60	1	4		
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York			1	1.4		
IV	North Carolina			2	24		
VIII	North Dakota						
V	Ohio	1	275	3	367		
VI	Oklahoma						
X	Oregon						
III	Pennsylvania			1	20		
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee			2	60		
VI	Texas			9	930	8	395
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia	1	290				
V	Wisconsin						
VIII	Wyoming						
	TOTAL	7	990	35	2116.4	10	477
	Region I	1	65	5	57		
	II			1	1.4		
	III	1	290	2	40		
	IV			8	246.5	1	75
	V	4	615	5	378.5	1	7
	VI			12	1376.5	8	395
	VII						
	VIII						
	IX	1	20		16.5		
	X						

Note:

(1) This indicates the number of plants in a given state which produce the given type of rubber. In some instances that type is not the primary product. It may also indicate captive production.

Source: Foster D. Snell, Inc. analysis of "Chemical Profiles" Oil, Paint & Drug Reporter; Ruebensaal's The Rubber Industry Statistical Report

TABLE II-11 (3)

		Butyl Rubber		Chlorosulfonated Polyethylene (Hypalon)		E-P Elastomers	
		No. of Plants(1)	Production KKKg/yr	No. of Plants(1)	Production KKKg/yr	No. of Plants(1)	Production KKKg/yr
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana	2	86.5			3	88
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	1	76	1	21.5	2	77.8
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	3	162.5	1	21.5	5	165.8
Region	I						
	II						
	III						
	IV						
	V						
	VI	3	162.5	1	21.5	5	165.8
	VII						
	VIII						
	IX						
	X						

Note:

(1) This indicates the number of plants in a given state which produce the given type of rubber. In some instances that type is not the primary product. It may also indicate captive production.

Source: Foster D. Snell, Inc. analysis of "Chemical Profiles" Oil, Paint & Drug Reporter; Ruebensaal's The Rubber Industry Statistical Report

TABLE II-11 (4)

		Epichlorohydrin Elastomers		Fluoro Rubbers		Isocyanate Type Rubbers	
		No. of Plants (1)	Production KKKg/yr	No. of Plants (1)	Production KKKg/yr	No. of Plants (1)	Production KKKg/yr
IV	Alabama			1	0.05		
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana					3	112
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan						
V	Minnesota			1	0.05		
IV	Mississippi	1	4.5				
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey			1	0.4	1	48
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio	1	4.5			1	18.2
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas					3	152
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia					3	154.3
V	Wisconsin						
VIII	Wyoming						
	TOTAL	2	9	3	0.5	11	484.5
Region	I						
	II			1	0.4	1	48
	III					3	154.3
	IV	1	4.5	1	0.05		
	V	1	4.5	1	0.05	1	18.2
	VI					6	264
	VII						
	VIII						
	IX						
	X						

Note:

(1) This indicates the number of plants in a given state which produce the given type of rubber. In some instances that type is not the primary product. It may also indicate captive production.

Source: Foster D. Snell, Inc. analysis of "Chemical Profiles" Oil, Paint & Drug Reporter; Ruebensaal's The Rubber Industry Statistical Report

TABLE II-11 (5)

		Isoprene Rubbers, Synthetic		Neoprene		Polysulfides	
		No. of Plants (1)	Production KKKg/yr	No. of Plants (1)	Production KKKg/yr	No. of Plants (1)	Production KKKg/yr
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky			1	122		
VI	Louisiana			1	35		
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	1	2.2			1	9.1
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio	1	32				
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	2	107.3	1	20		
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	4	141.5	3	177	1	9.1
	Region I						
	II	1	2.2			1	9.1
	III						
	IV			1	122		
	V	1	32				
	VI	2	107.3	2	55		
	VII						
	VIII						
	IX						
	X						

Note:

(1) This indicates the number of plants in a given state which produce the given type of rubber. In some instances that type is not the primary product. It may also indicate captive production.

Source: Foster D. Snell, Inc. analysis of "Chemical Profiles" Oil, Paint & Drug Reporter; Ruebensaal's The Rubber Industry Statistical Report

TABLE II-11 (6)

		Silicone Rubber		Urethane Rubber		Vulcanized Oils	
		No. of Plants$^{(1)}$	Production KKKg/yr	No. of Plants$^{(1)}$	Production KKKg/yr	No. of Plants$^{(1)}$	Production KKKg/yr
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	1	4	1	N.A.		
VIII	Colorado						
I	Connecticut	1	4	1	N.A.		
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois			1	N.A.		
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan	2	5.3				
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	1	9.1	1/3	2.2/N.A	1	N.A.
VI	New Mexico						
II	New York	1	2.7	1	N.A.		
IV	North Carolina						
VIII	North Dakota						
V	Ohio			2	5		
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas			1	3.6		
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia	1	1.5	1			
V	Wisconsin						
VIII	Wyoming						
	TOTAL	7	26.6	5/7	17.6/N.A	1	N.A
I	Region	1	4	1	N.A.	1	N.A
II		2	11.8	1/4	2.2/N.A.		
III		1	1.5	1	6.8		
IV							
V		2	5.3	2/1	5/N.A.		
VI				1	3.6		
VII							
VIII							
IX		1	4	1	N.A.		
X							

Notes:

(1) This indicates the number of plants in a given state which produce the given type of rubber. In some instances that type is not the primary product. It may also indicate captive production.

(2) N.A. - not available.

Source: Foster D. Snell, Inc. analysis of "Chemical Profiles" Oil, Paint & Drug Reporter, Ruebensaal's The Rubber Industry Statistical Report.

TABLE II-12

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF EMPLOYMENT IN SIC 2822

		Employment(1)
IV	Alabama	110
X	Alaska	
IX	Arizona	
VI	Arkansas	
IX	California	360
VIII	Colorado	
I	Connecticut	110
III	Delaware	375
IV	Florida	
IV	Georgia	120
IX	Hawaii	
X	Idaho	
V	Illinois	300
V	Indiana	
VII	Iowa	
VII	Kansas	
IV	Kentucky	1.350
VI	Louisiana	2.880
I	Maine	
III	Maryland	
I	Massachusetts	110
V	Michigan	225
V	Minnesota	50
IV	Mississippi	150
VII	Missouri	
VIII	Montana	
VII	Nebraska	
IX	Nevada	
I	New Hampshire	
II	New Jersey	190
VI	New Mexico	
II	New York	75
IV	North Carolina	240
VIII	North Dakota	
V	Ohio	1.500
VI	Oklahoma	
X	Oregon	
III	Pennsylvania	75
I	Rhode Island	
IV	South Carolina	
VIII	South Dakota	
IV	Tennessee	225
VI	Texas	8.075
VIII	Utah	
I	Vermont	
III	Virginia	
X	Washington	
III	West Virginia	375
V	Wisconsin	
VIII	Wyoming	
	TOTAL	16.895

Region	I	220
	II	265
	III	825
	IV	2.195
	V	2.075
	VI	10.955
	VII	
	VIII	
	IX	360
	X	

(1) Employment figures are estimated on the 1972 Census of Manufacturers and extrapolated in accordance with production information from this study.

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report.

The following data provides an estimate of production unit size distribution by employment on a national basis for SIC 2822 as a whole.

Table II-13 -- Production Unit Size Distribution By Employment, SIC 2822 (National Basis)

Number of Production Units	Number of Employees							
	1-4	5-9	10-19	20-49	50-99	100-249	500-999	1,000-2,499
120	20	12	18	16	9	12	16	4

Source: Foster D. Snell, Inc.

From the above information, it can be seen that 63% of the production units have less than 100 employees. However, except for the four facilities with between 1,000 and 2,499 employees, the distribution is rather even in all categories.

2.2.3 Plant Age Distribution

Plant age distributions for the major synthetic rubbers (accounting for over 90% of SIC 2822 production in 1974) are presented on a product by product basis in a series of tables:

- Table II-14 -- Styrene-Butadiene
- Table II-15 -- Polybutadiene
- Table II-16 -- Acrylonitrile-Butadiene
- Table II-17 -- Neoprene
- Table II-18 -- Butyl
- Table II-19 -- Ethylene-Propylene
- Table II-20 -- Isoprene

The bulk of the oldest and newest production units are those manufacturing styrene-butadiene rubber which was the type produced in the greatest quantity in 1974. Production units for all other rubber types are evenly distributed in regards to age.

Estimated plant age distribution for the plants presented in Tables II-14 through II-20 are summarized in Table II-21.

TABLE II-14

ESTIMATED PLANT AGE DISTRIBUTION OF STYRENE-BUTADIENE SYNTHETIC RUBBER PRODUCTION UNITS

		Number of Production Units	Plant Age			
			0-9 Years	10-19 Years	20-29 Years	30+ Years
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California	2	1	1		
VIII	Colorado					
I	Connecticut	3		2		1
III	Delaware	1			1	
IV	Florida					
IV	Georgia	2	2			
IX	Hawaii					
X	Idaho					
V	Illinois	1				1
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky	2	1			1
VI	Louisiana	3	1			2
I	Maine					
III	Maryland					
I	Massachusetts	2	1	1		
V	Michigan	1			1	
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York	1			1	
IV	North Carolina	2	1	1		
VIII	North Dakota					
V	Ohio	3				3
VI	Oklahoma					
X	Oregon					
III	Pennsylvania	1		1		
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee	2	1	1		
VI	Texas	9	2	1	1	5
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia					
V	Wisconsin					
VIII	Wyoming					
	TOTAL	35	10	8	4	13
	Region I	5	1	3		1
	II	1			1	
	III	2		1	1	
	IV	8	5	2		1
	V	5			1	4
	VI	12	3	1	1	7
	VII					
	VIII					
	IX	2	1	1		
	X					

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-15

ESTIMATED PLANT AGE DISTRIBUTION OF POLYBUTADIENE PRODUCTION UNITS

		Number of Production Units	Plant Age				
			0-9 Years	10-19 Years	20-29 Years	30+ Years	N.A.
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois	1					1
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky	1		1			
VI	Louisiana						
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	8		1	5		2
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	10		1	6		3
Region	I						
	II						
	III						
	IV	1			1		
	V	1					1
	VI	8		1	5		2
	VII						
	VIII						
	IX						
	X						

N.A. = Not Available.

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-16

ESTIMATED PLANT AGE DISTRIBUTION OF ACRYLONITRILE-BUTADIENE SYNTHETIC RUBBER PRODUCTION UNITS

		Number of Production Units	Plant Age			
			0-9 Years	10-19 Years	20-29 Years	30+ Years
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California					
VIII	Colorado					
I	Connecticut					
III	Delaware					
IV	Florida					
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois					
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky	2	1			1
VI	Louisiana	2	1			1
I	Maine					
III	Maryland					
I	Massachusetts	1		1		
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York					
IV	North Carolina					
VIII	North Dakota					
V	Ohio	4		3		1
VI	Oklahoma					
X	Oregon					
III	Pennsylvania					
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	1				1
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia					
V	Wisconsin					
VIII	Wyoming					
	TOTAL	10	2	4		4
	Region I	1		1		
	II					
	III					
	IV	2	1			1
	V	4		3		1
	VI	3	1			2
	VII					
	VIII					
	IX					
	X					

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-17

ESTIMATED PLANT AGE DISTRIBUTION OF NEOPRENE PRODUCTION UNITS

		Number of Production Units	Plant Age			
			0-9 Years	10-19 Years	20-29 Years	30+ Years
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California					
VIII	Colorado					
I	Connecticut					
III	Delaware					
IV	Florida					
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois					
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky	1				1
VI	Louisiana	1	1			
I	Maine					
III	Maryland					
I	Massachusetts					
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York					
IV	North Carolina					
VIII	North Dakota					
V	Ohio					
VI	Oklahoma					
X	Oregon					
III	Pennsylvania					
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	1	1			
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia					
V	Wisconsin					
VIII	Wyoming					
	TOTAL	3	2			1
	Region I					
	II					
	III					
	IV	1				1
	V					
	VI	2	2			
	VII					
	VIII					
	IX					
	X					

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-18

ESTIMATED PLANT AGE DISTRIBUTION OF BUTYL RUBBER PRODUCTION UNITS

		Number of Production Units	Plant Age			
			0-9 Years	10-19 Years	20-29 Years	30+ Years
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California					
VIII	Colorado					
I	Connecticut					
III	Delaware					
IV	Florida					
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois					
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky					
VI	Louisiana	2		1		1
I	Maine					
III	Maryland					
I	Massachusetts					
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York					
IV	North Carolina					
VIII	North Dakota					
V	Ohio					
VI	Oklahoma					
X	Oregon					
III	Pennsylvania					
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	1				1
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia					
V	Wisconsin					
VIII	Wyoming					
	TOTAL	3		1		2
	Region I					
	II					
	III					
	IV					
	V					
	VI	3		1		2
	VII					
	VIII					
	IX					
	X					

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-19

ESTIMATED PLANT DISTRIBUTION OF ETHYLENE-PROPYLENE ELASTOMER PRODUCTION UNITS

		Number of Production Units	Plant Age			
			0-9 Years	10-19 Years	20-29 Years	30+ Years
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California					
VIII	Colorado					
I	Connecticut					
III	Delaware					
IV	Florida					
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois					
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky					
VI	Louisiana	3	1	2		
I	Maine					
III	Maryland					
I	Massachusetts					
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York					
IV	North Carolina					
VIII	North Dakota					
V	Ohio					
VI	Oklahoma					
X	Oregon					
III	Pennsylvania					
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	2	1	1		
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia					
V	Wisconsin					
VIII	Wyoming					
	TOTAL	5	2	3		
	Region I					
	II					
	III					
	IV					
	V					
	VI	5	2	3		
	VII					
	VIII					
	IX					
	X					

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-20

ESTIMATED PLANT AGE DISTRIBUTION OF ISOPRENE ELASTOMER PRODUCTION UNITS

		Number of Production Units	Plant Age				
			0-9 Years	10-19 Years	20-29 Years	30+ Years	N.A.
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	1					1
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio	1		1			
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	2	1				1
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	4	1	1			2
	Region I						
	II	1					1
	III						
	IV						
	V	1		1			
	VI	1	1				1
	VII						
	VIII						
	IX						
	X						

N.A. = Not Available.

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

TABLE II-21

TOTAL ESTIMATED PLANT AGE DISTRIBUTION OF PRODUCTION UNITS FOR MAJOR SYNTHETIC RUBBERS, SIC 2822

		Number of Production Units	Plant Age 0-9 Yrs	10-19 Yrs	20-29 Yrs	Over 30 Yrs	N.A.
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	2	1	1			
VIII	Colorado						
I	Connecticut	3		2		1	
III	Delaware	1			1		
IV	Florida						
IV	Georgia	2	2				
IX	Hawaii						
X	Idaho						
V	Illinois	2				1	1
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky	6	2	1		3	
VI	Louisiana	11	4	3		4	
I	Maine						
III	Maryland						
I	Massachusetts	3	1	2			
V	Michigan	1			1		
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	1					1
VI	New Mexico						
II	New York	1			1		
IV	North Carolina	2	1	1			
VIII	North Dakota						
V	Ohio	8		4		4	
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	1		1			
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee	2	1	1			
VI	Texas	24	6	7	1	7	3
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	70	18	23	4	20	5
	Region I	6	1	4			1
	II	2			1	1	
	III	2		1	1		
	IV	12	6	3		3	
	V	11		4	1	5	1
	VI	35	10	10	1	11	3
	VII						
	VIII						
	IX	2	1	1			
	X						

N.A. = Not Available.

Source: Rubber Red Book (1975), OPD Chemical Profiles, Ruebensaal's, The Rubber Industry Statistical Report and Foster D. Snell, Inc. estimates.

- Eighteen of the production units are in the range of 0-9 years old.
- Twenty-three are between 10-19 years old.
- Only four are 20-29 years old.
- Twenty are over 30 years old.

2.3 Structure Of The Man-Made Fiber Industry, SICs 2823 And 2824

This sub-section discusses the industry structure for both fiber producing segments of the plastics materials and synthetics industry.

- SIC 2823, Cellulosic Man-Made Fibers
- SIC 2824, Man-Made Fibers, Non-Cellulosic.

For the man-made fiber industry, the value added by manufacture was $2,283.8 million according to the 1972 Census of Manufacturers, while the value of shipments was $4,229.3 million. There were over 95 thousand employees working in this industry in 1972. The split between SICs 2823 and 2824 for these values were as follows:

- For SIC 2823, the value added by manufacture was $252.7 million, value of shipments was $627.9 million and employment was 19,000 total workers.
- For SIC 2824, the value added by manufacture was $2,031.1 million, the value of shipments was $3,601.4 million and employment totalled 76,300 workers.

From these figures, it is apparent that the cellulosic fiber industry is significantly smaller than the non-cellulosic segment of SIC 282. In fact, SIC 2823 is the smallest segment of SIC 282 in terms of employment, value added by manufacture, value of shipments, number of establishments and production volume on a weight basis. The non-cellulosic fiber industry, SIC 2824 is exceeded in the above terms within SIC 282 only by the plastic materials and resins group, SIC 2821.

The products of the fiber industry find use throughout the U.S. economy. For example, major end-uses of cellulosic and non-cellulosic fibers are listed below in order of product mix importance.(1)

- Broad woven goods: 43%
- Flat knit goods: 15%
- Non-woven goods: 12%
- Tires: 6%

All of these end-uses are important in the economy.

There are two important cellulosic fiber classes produced by SIC 2823:

- Rayon
- Acetates and triacetates

and four important non-cellulosic fiber classes produced by SIC 2824:

- Polyesters
- Nylon and aramids
- Acrylics and modacrylics
- Polyolefins and vinyon.

In general, this report focuses on the above listed cellulosic and non-cellulosic fibers. These materials represent over 95% of production in SICs 2823 and 2824.

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(1) Foster D. Snell, Inc., Industrial Energy Study Of The Plastics And Rubber Industries, SICs 282 and 30. Contract Number: 14-01-0001-1655, U.S. Department of Interior, Bureau of Mines, Washington, D.C. (1974).

2.3.1 Geographic Distribution Of Production Units And Employment, Man-Made Fiber Industries, SICs 2823 And 2824

Table II-22 presents the estimated 1974 geographic distribution of production units and employment for the man-made fiber industries.

- Our survey has found that there are approximately 166 production units within these industries.
- The cellulosic and non-cellulosic fiber industries are both concentrated in the South Atlantic states near the large textile mills. These states of high concentration include Tennessee, North Carolina, South Carolina and Virginia.

Employment values are given as an aggregate for both SICs comprising the fiber industry. This approach was taken because in many cases there are several production units at one site and in some instances these units are in both SICs 2823 and 2824.

2.3.2 Plant Age Distribution

Estimated plant age distributions for the fiber groups of SIC 282 were developed with the assistance of the Textile Economics Bureau.

2.3.2.1 Cellulosic Man-Made Fiber Industry, SIC 2823

Table II-23 presents the estimated production unit age distribution for this industry. The majority of production units (10 out of 13 still in production) are over 30 years of age. One production unit is in the range of 10 to 20 years old and the remaining two began production 20 to 30 years ago.

TABLE II-22

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF PRODUCTION UNITS AND EMPLOYMENT -- SICs 2823 AND 2824

		Manmade Fibers Cellulosic SIC 2823		Manmade Fibers Non-Cellulosic SIC 2824					
		Rayon	Acetate and Triacetate	Nylon and Aramid	Acrylic and Modacrylic	Olefin and Vinyon	Polyester	Other	Employment (1)
IV	Alabama	1		2	1M	3	3		6,000
X	Alaska								
IX	Arizona								
VI	Arkansas								
IX	California					2			(D) (2)
VIII	Colorado								
I	Connecticut					1			(D)
III	Delaware			1			1		3,000
IV	Florida			2	1	2		1B	3,000
IV	Georgia		1	1		9			3,000
IX	Hawaii								
X	Idaho								
V	Illinois								
V	Indiana								
VII	Iowa			1		1			(D)
VII	Kansas								
IV	Kentucky								
VI	Louisiana					1			(D)
I	Maine					1			(D)
III	Maryland		1	1		4	1	1S	3,000
I	Massachusetts					2		1X	(D)
V	Michigan					1			(D)
V	Minnesota					1			(D)
IV	Mississippi								
VII	Missouri					2			(D)
VIII	Montana								
VII	Nebraska								
IX	Nevada								
I	New Hampshire								
II	New Jersey					3		1X	(D)
VI	New Mexico								
II	New York			1		3 1V		1F	(D)
IV	North Carolina			4		4	1	1X	15,000
VIII	North Dakota								
V	Ohio					1	1		(D)
VI	Oklahoma								
X	Oregon								
III	Pennsylvania		1	1		2 1V	1		3,000
I	Rhode Island					1			(D)
IV	South Carolina		1	10	1	3	10	1B	18,000
VIII	South Dakota								
IV	Tennessee	2	1	6	1M	5	5		15,000
VI	Texas								(D)
VIII	Utah								
I	Vermont								
III	Virginia	2	2	6 1A	2	3	4	3FXP	15,000
X	Washington					1			(D)
III	West Virginia	1		1			1		3,000
V	Wisconsin					1			(D)
VIII	Wyoming								
	TOTAL	6	7	38	6	60	39	10	105,000
Region	I					5		1	3,000
	II			1		7	1	2	6,000
	III	3	4	11	2	10	8	4	27,000
	IV	3	3	25	4	26	29	3	60,000
	V					4	1		3,000
	VI					2			(D)
	VII			1		3			3,000
	VIII								
	IX					2			(D)
	X					1			(D)

(1) Employment is total for both SIC 2823 and 2824 as in many cases there are several production units at one site and in some instances these units are in both SICs.

(2) (D) = data not presented to avoid disclosure.

Key:

A - Aramid
B - Biconstituent
F - Fluorocarbon
M - Modacrylic

P - Polycarbonate
S - Saran
V - Vinyon
X - Spandex

SIC 2823 = Cellulosic Manmade Fiber Industry
SIC 2824 = Non-Cellulosic Manmade Fiber Industry

Source: Textile Organon, Sept. 1975. Snell analysis of information supplied by the Textile Economics Bureau and 1972 Census of Manufacturers, U. S. Department of Commerce, Publication No. MC72(2)-28B

TABLE II-23

ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF PLANT AGE
CELLULOSIC MANMADE FIBERS
SIC 2823

		Total No. of Plants	Plant Age (Years)				
			5 or Less	5-10	10-20	20-30	30 or more
IV	Alabama	1				1	
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida						
IV	Georgia	1					1
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland	1					1
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	1					1
I	Rhode Island						
IV	South Carolina	1				1	
VIII	South Dakota						
IV	Tennessee	3			1		2
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	4					4
X	Washington						
III	West Virginia	1					1
V	Wisconsin						
VIII	Wyoming						
	TOTAL	13			1	2	10
	Region I						
	II						
	III	7					7
	IV	6			1	2	3
	V						
	VI						
	VII						
	VIII						
	IX						
	X						

Source: "Base Book of Textile Statistics", Textile Organon, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January 1962, and Foster D. Snell, Inc. analysis of information from subsequent issues of Textile Organon.

2.3.2.2 Non-Cellulosic Man-Made Fiber Industry, SIC 2824

Estimated production unit age distribution for this industry are presented in Table II-24.

As can be seen from a comparison of Tables II-23 and II-24, SIC 2824 is a newer industry than SIC 2823. A summary of production unit ages is provided below.

Table II-25 -- Summary Of Ages Of Production Units, SIC 2824

Total Number of Production Units Identified	Production Unit Age (Years)				
	4 or Less	5-9	10-19	20-29	30 or More
153	52	46	40	11	4

Source: Foster D. Snell, Inc.

Over 66% of the production units are between less than 5 years old to 10 years in age. Only approximately 3% are thirty years old or more.

The oldest units are generally those producing nylon and spandex. The newest production units are those manufacturing polyolefins, polyesters and some small volume fibers such as fluorocarbons and polycarbonates.

Table II-26 through II-30 present production unit ages of the individual fibers in SIC 2824.

2.3.3 Geographic Distribution Of 1974 Capacities And Production

Much of the information concerning capacities and production for the cellulosic and non-cellulosic fiber industries cannot be presented on a state basis in order to prevent disclosure of proprietary information.

TABLE II-24

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF PLANT AGE OF NON-CELLULOSIC SYNTHETIC FIBERS, SIC 2824

		Number of Production Units	Plant Age				
			0-4 Years	5-9 Years	10-19 Years	20-29 Years	30+ Years
IV	Alabama	9	4	3	1	1	
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	2		1	1		
VIII	Colorado						
I	Connecticut	1	1				
III	Delaware	2	1				1
IV	Florida	6	3	1	1	1	
IV	Georgia	10	4	5	1		
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa	2			2		
VII	Kansas						
IV	Kentucky						
VI	Louisiana	1		1			
I	Maine	1		1			
III	Maryland	7	2	1	1	2	1
I	Massachusetts	3		1	2		
V	Michigan	1		1			
V	Minnesota	1	1				
IV	Mississippi						
VII	Missouri	2	2				
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	4		1	3		
VI	New Mexico						
II	New York	7	3		4		
IV	North Carolina	20	9	6	3	2	
VIII	North Dakota						
V	Ohio	2	1		1		
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	5	2	1	1		1
I	Rhode Island	1		1			
IV	South Carolina	25	9	11	3	2	
VIII	South Dakota						
IV	Tennessee	17	1	6	8	2	
VI	Texas	1	1				
VIII	Utah						
I	Vermont						
III	Virginia	19	6	4	7	1	1
X	Washington	1	1				
III	West Virginia	2		1	1		
V	Wisconsin	1	1				
VIII	Wyoming						
	TOTAL	153	52	46	40	11	4
	Region I	6	1	3	2		
	II	11	3	1	2	3	4
	III	35	11	2	11	8	
	IV	87	30	32	16		
	V	5	3	1	1		
	VI	2	1	1			
	VII	4	2		2		
	VIII						
	IX	2		1	1		
	X	1	1				

Source: "Base Book of Textile Statistics", Textile Organon, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January, 1962, and Foster D. Snell, Inc., analysis of information from subsequent issues of Textile Organon.

TABLE II-26
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF PLANT AGE
SYNTHETIC FIBERS -- SIC 2824
Nylon and Aramid

		Total No. of Plants	Plant Age (Years)				
			5 or Less	5-10	10-20	20-30	30 or more
IV	Alabama	2	1		1		
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware	1					1
IV	Florida	2		1		1	
IV	Georgia	1		1			
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa	1			1		
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland	1			1		
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York	1			1		
IV	North Carolina	4	1	1	1	1	
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	1			1		
I	Rhode Island						
IV	South Carolina	10	2	5	3		
VIII	South Dakota						
IV	Tennessee	6		2	2	2	
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	7	2	1	3		1
X	Washington						
III	West Virginia	1			1		
V	Wisconsin						
VIII	Wyoming						
	TOTAL	38	6	11	15	4	2
Region	I						
	II	1			1		
	III	11	2	1	6		2
	IV	25	4	10	7	4	
	V						
	VI						
	VII	1			1		
	VIII						
	IX						
	X						

Source: "Base Book of Textile Statistics", Textile Organon, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January 1962, and Foster D. Snell, Inc. analysis of information from subsequent issues of Textile Organon

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TABLE II 27
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF PLANT AGE
SYNTHETIC FIBERS -- SIC 2824
Other
Non-Cellulosic

		Total No. of Plants	Plant Age (Years) 5 or Less	5-10	10-20	20-30	30 or more
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida	1	1B				
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland	1					1S
I	Massachusetts	1			1X		
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	1			1X		
VI	New Mexico						
II	New York	1	1F				
IV	North Carolina	1	1X				
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina	1	1B				
VIII	South Dakota						
IV	Tennessee						
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	3	1P		2FX		
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	10	5		4		1
Region	I	1			1		
	II	2	1		1		
	III	4	1		2		1
	IV	3	3				
	V						
	VI						
	VII						
	VIII						
	IX						
	X						

Key:
B - biconstituent
S - Saran
X - Spandex
F - Fluorocarbon
P - Polycarbonate

Source: "Base Book of Textile Statistics", Textile Organon, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January 1962, and Foster D. Snell, Inc. analysis of information from subsequent issues of Textile Organon.

TABLE II-28
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF PLANT AGE
SYNTHETIC FIBERS -- SIC 2824
Polyester

		Total No of Plants	Plant Age (Years)				
			5 or Less	5-10	10-20	20-30	30 or more
IV	Alabama	3	2	1			
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware	1	1				
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland	1		1			
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York	1			1		
IV	North Carolina	11	5	3	2	1	
VIII	North Dakota						
V	Ohio	1			1		
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	1		1			
I	Rhode Island						
IV	South Carolina	10	5	5			
VIII	South Dakota						
IV	Tennessee	5	1		4		
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	4	2	2			
X	Washington						
III	West Virginia	1		1			
V	Wisconsin						
VIII	Wyoming						
	TOTAL	39	16	14	8	1	
Region	I						
	II	1			1		
	III	8	3	5			
	IV	29	13	9	6	1	
	V	1			1		
	VI						
	VII						
	VIII						
	IX						
	X						

Source: "Base Book of Textile Statistics", *Textile Organon*, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January 1962, and Foster D. Snell, Inc. analysis of information from subsequent issues of *Textile Organon*

TABLE II-29
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF PLANT AGE
SYNTHETIC FIBERS -- SIC 2824
Polyolefins and Vinyon

		Total No. of Plants	Plant Age (Years)				
			5 or Less	5-10	10-20	20-30	30 or more
IV	Alabama	3	1	2			
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	2		1	1		
VIII	Colorado						
I	Connecticut	1	1				
III	Delaware						
IV	Florida	2	2				
IV	Georgia	9	4	4	1		
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa	1			1		
VII	Kansas						
IV	Kentucky						
VI	Louisiana	1		1			
I	Maine	1		1			
III	Maryland	4	2			2	
I	Massachusetts	2		1	1		
V	Michigan	1		1			
V	Minnesota	1	1				
IV	Mississippi						
VII	Missouri	2	2				
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	3		1	2		
VI	New Mexico						
II	New York	4	2		2		
IV	North Carolina	4	2	2			
VIII	North Dakota						
V	Ohio	1	1				
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	3	2				1
I	Rhode Island	1		1			
IV	South Carolina	3	1	1		1	
VIII	South Dakota						
IV	Tennessee	5		4	1		
VI	Texas	1	1				
VIII	Utah						
I	Vermont						
III	Virginia	3	1	1		1	
X	Washington	1	1				
III	West Virginia						
V	Wisconsin	1	1				
VIII	Wyoming						
	TOTAL	60	25	21	9	4	1
Region	I	5	1	3	1		
	II	7	2	1	4		
	III	10	5	1		3	1
	IV	26	10	13	2	1	
	V	4	3	1			
	VI	2	1	1			
	VII	3	2		1		
	VIII						
	IX	2		1	1		
	X	1	1				

Source: "Base Book of Textile Statistics", Textile Organon, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January 1962, and Foster D. Snell, Inc. analysis of information from subsequent issues of Textile Organon

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TABLE II-31
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF PLANT AGE
SYNTHETIC FIBERS -- SIC 2824
Acrylic and Modacrylic

		Total No. of Plants	Plant Age (Years)				
			5 or Less	5-10	10-20	20-30	30 or more
IV	Alabama	1				1	
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida	1			1		
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland						
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina	1				1	
VIII	South Dakota						
IV	Tennessee	1			1		
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	2			2		
X	Washington						
III	West Virginia						
V	Wisconsin						
VIII	Wyoming						
	TOTAL	6			4	2	
Region	I						
	II						
	III	2			2		
	IV	4			2	2	
	V						
	VI						
	VII						
	VIII						
	IX						
	X						

Source: "Base Book of Textile Statistics", Textile Organon, Vol. XXXIII No. 1, New York, Textile Economics Bureau, January 1962, and Foster D. Snell, Inc. analysis of information from subsequent issues of Textile Organon.

2.3.3.1 Cellulosic Man-Made Fiber Industry, SIC 2823

Table II-31 presents the estimated geographic distribution of cellulosic fiber capacities for 1974. Table II-32 does the same for production.

- Total reported capacity was 3,435 KKKg in 1974. Capacity was split almost equally between the rayon and acetate classes of fibers.
- Total reported cellulosic fiber production was approximately 537.6 KKKg in 1974. This was only 15% of the reported capacity.

Most production in this industry centered in the South Atlantic states.

2.3.3.2 Non-Cellulosic Man-Made Fiber Industry, SIC 2824

Table II-33 presents the estimate geographic distribution of non-cellulosic man-made fiber capacities for 1974. Table II-34 does the same for production.

- Total reported capacity for 1974 was 17,592 KKKg. The greatest capacity exists for polyester based fibers followed by the nylons. These two fibers account for approximately 81% of U.S. capacity for fiber production.
- Total reported production was 137,000 KKKg in 1974. This represented an over 77% capacity utilization which was over five times that for cellulosic fibers.

As in the case of cellulosic fibers, non-cellulosic production is centered in the South Atlantic states near the large textile mills.

TABLE II-31
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF CELLULOSIC FIBER CAPACITIES --SIC 2823 (KKKg/yr)

		Rayon Filament	Rayon Staple And Tow	Acetate Filament	Acetate Staple And Tow
IV	Alabama		(D)(1)		
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California				
VIII	Colorado				
I	Connecticut				
III	Delaware				
IV	Florida				
IV	Georgia			(D)	
IX	Hawaii				
X	Idaho				
V	Illinois				
V	Indiana				
VII	Iowa				
VII	Kansas				
IV	Kentucky				
VI	Louisiana				
I	Maine				
III	Maryland			(D)	
I	Massachusetts				
V	Michigan				
V	Minnesota				
IV	Mississippi				
VII	Missouri				
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey				
VI	New Mexico				
II	New York				
IV	North Carolina				
VIII	North Dakota				
V	Ohio				
VI	Oklahoma				
X	Oregon				
III	Pennsylvania			(D)	
I	Rhode Island				
IV	South Carolina			(D)	(D)
VIII	South Dakota				
IV	Tennessee	(D)	(D)	(D)	(D)
VI	Texas				
VIII	Utah				
I	Vermont				
III	Virginia		(D)	(D)	(D)
X	Washington				
III	West Virginia	(D)	(D)		
V	Wisconsin				
VIII	Wyoming				
	TOTAL	210	1595	850	780
	Region I				
	II				
	III	(D)	(D)	475	(D)
	IV	(D)	(D)	375	(D)
	V				
	VI				
	VII				
	VIII				
	IX				
	X				

[1] (D) = data not presented to avoid disclosure.

Source: Snell analysis of information supplied by the Textile Economics Bureau and from Textile Organon, Vol. XLVI, No. 9, New York, Textile Economics Bureau, September 1975.

TABLE II-32
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF
CELLULOSIC FIBER PRODUCTION
--SIC 2823 (KKKg/yr)

		Rayon Filament	Rayon Staple & Tow	Acetate Filament	Acetate Staple & Tow
IV	Alabama		(D)[1]		
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California				
VIII	Colorado				
I	Connecticut				
III	Delaware				
IV	Florida				
IV	Georgia			(D)	
IX	Hawaii				
X	Idaho				
V	Illinois				
V	Indiana				
VII	Iowa				
VII	Kansas				
IV	Kentucky				
VI	Louisiana				
I	Maine				
III	Maryland			(D)	
I	Massachusetts				
V	Michigan				
V	Minnesota				
IV	Mississippi				
VII	Missouri				
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey				
VI	New Mexico				
II	New York				
IV	North Carolina				
VIII	North Dakota				
V	Ohio				
VI	Oklahoma				
X	Oregon				
III	Pennsylvania			(D)	
I	Rhode Island				
IV	South Carolina			(D)	
VIII	South Dakota				
IV	Tennessee	(D)	(D)	(D)	
VI	Texas				
VIII	Utah				
I	Vermont				
III	Virginia		(D)	(D)	
X	Washington				
III	West Virginia	(D)	(D)		
V	Wisconsin				
VIII	Wyoming				
	TOTAL	78.3	294.3	165	none reported
	Region I				
	II				
	III	(D)	(D)	92	
	IV	(D)	(D)	73	
	V				
	VI				
	VII				
	VIII				
	IX				
	X				

[1] (D) = data not presented to avoid disclosure.

Source: Snell analysis of information from Textile Organon, Volume XLVI, No. 1-2, New York, Textile Economics Bureau, January-February, 1975.

TABLE II-33
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION OF
NON-CELLULOSIC FIBER
CAPACITIES -- SIC 2824 (MMKg/yr)

		Nylon Filament	Nylon Staple And Tow	Acrylic and Modacrylic Staple and Tow	Polyester Filament	Polyester Staple and Tow	Polyolefin Filament	Polyolefin Staple and Tow	Other (1)
IV	Alabama	(D) (2)	(D)	(D)	(C) (3)	(D)	NA		
X	Alaska								
IX	Arizona								
VI	Arkansas								
IX	California						(D)		
VIII	Colorado								
I	Connecticut						(D)		
III	Delaware	(D)	(D)		(D)				
IV	Florida	(D)	(D)	(D)			(D)		(D)
IV	Georgia	(D)					NA	(D)	
IX	Hawaii								
X	Idaho								
V	Illinois								
V	Indiana								
VII	Iowa	(D)					(D)		
VII	Kansas								
IV	Kentucky								
VI	Louisiana						(D)		
I	Maine						(D)		
III	Maryland	(D)			(D)		NA	(D)	(D)
I	Massachusetts						(D)		(D)
V	Michigan						(D)		
V	Minnesota						(D)		
IV	Mississippi								
VII	Missouri						(D)		
VIII	Montana								
VII	Nebraska								
IX	Nevada								
I	New Hampshire								
II	New Jersey						(D)		(D)
VI	New Mexico								
II	New York	(D)			(D)		(D)		(D)
IV	North Carolina	265	(D)		1365	(D)	NA		(D)
VIII	North Dakota								
V	Ohio				(D)		(D)		
VI	Oklahoma								
X	Oregon								
III	Pennsylvania	(D)			(D)		(D)		
I	Rhode Island						(D)	(D)	
IV	South Carolina	1190	570	(D)	1230	(D)	(D)	(D)	(D)
VIII	South Dakota								
IV	Tennessee	615	375	(D)	990 (3)	(D)	NA	(D)	
VI	Texas						(D)		
VIII	Utah								
I	Vermont								
III	Virginia	945	(D)	(D)	(D)	(D)	(D)	(D)	(D)
X	Washington						(D)		
III	West Virginia	(D)	(D)		(D)				
V	Wisconsin						(D)		
VIII	Wyoming								
	TOTAL	4215	1730	1770	4080	4290	1120	355	35 (2)
Region	I						250	(D)	(D)
	II	(D)			(D)		130		(D)
	III	1475	575	(D)	375	(D)	190	(D)	(D)
	IV	2730	1155	(D)	3585	(D)	490	(D)	(D)
	V				(D)		(D)		
	VI						(D)		
	VII	(D)					(D)		
	VIII								
	IX						(D)		
	X								

Notes
(1) Primarily saran and spandex
(2) (D) = data not presented to avoid disclosure
(3) (C) = polyester filament capacities for AL and TN combined to avoid disclosure

Source: Snell analysis of information supplied by the Textile Economics Bureau and from Textile Organon, Vol. XLVI, No. 9, New York, Textile Economics Bureau, September 1975.

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TABLE II-34
ESTIMATED 1974
GEOGRAPHIC DISTRIBUTION
OF NON-CELLULOSIC FIBER
PRODUCTION -- SIC 2824 [illegible]

		Nylon Filament	Nylon Staple and Tow	Acrylic and Modacrylic Staple and Tow	Polyester Filament	Polyester Staple and Tow	Polyolefin Filament	Polyolefin Staple and Tow	Other (1)
IV	Alabama	(D)(2)	(D)	(D)	(3)	(D)	NA		
X	Alaska								
IX	Arizona								
VI	Arkansas								
IX	California						(D)		
VIII	Colorado								
I	Connecticut						(D)		
III	Delaware	(D)	(D)		(D)				
IV	Florida	(D)	(D)	(D)			(D)		(D)
IV	Georgia	(D)					NA	(D)	
IX	Hawaii								
X	Idaho								
V	Illinois								
V	Indiana								
VII	Iowa	(D)					(D)		
VII	Kansas								
IV	Kentucky								
VI	Louisiana						(D)		
I	Maine						(D)		
III	Maryland	(D)			(D)		NA	(D)	(D)
I	Massachusetts						(D)		(D)
V	Michigan						(D)		
V	Minnesota						(D)		
IV	Mississippi								
VII	Missouri						(D)		
VIII	Montana								
VII	Nebraska								
IX	Nevada								
I	New Hampshire								
II	New Jersey						(D)		(D)
VI	New Mexico								
II	New York	(D)			(D)		(D)		(D)
IV	North Carolina	215	(D)		1040	(D)	NA		(D)
VIII	North Dakota								
V	Ohio				(D)		(D)		
VI	Oklahoma								
X	Oregon								
III	Pennsylvania	(D)			(D)		(D)		
I	Rhode Island						(D)	(D)	
IV	South Carolina	970	410	(D)	935	(D)	(D)	(D)	(D)
VIII	South Dakota								
IV	Tennessee	500	275	(D)	750(3)	(D)	NA	(D)	
VI	Texas						(D)		
VIII	Utah								
I	Vermont								
III	Virginia	770	(D)	(D)	(D)	(D)	(D)	(D)	(D)
X	Washington						(D)		
III	West Virginia	(D)	(D)		(D)				
V	Wisconsin						(D)		
VIII	Wyoming								
	TOTAL	3430	1245	1390	3100	3340	1020	150	25
	Region I						230	(D)	(D)
	II	(D)			(D)		120		(D)
	III	1190	415	(D)	285	(D)	175	(D)	(D)
	IV	2225	830	(D)	2725	(D)	445	(D)	(D)
	V				(D)		(D)		
	VI						(D)		
	VII	(D)					(D)		
	VIII								
	IX						(D)		
	X								

(1) Primarily saran and spandex

(2) (D) = data not presented to avoid disclosure

(3) Polyester filament production for AL and TN combined to avoid disclosure

Source: Snell analysis of data presented in Textile Organon, Vol. XLVI No. 1-2, New York, Textile Economics Bureau, January-February 1975.

3. PROCESS DESCRIPTIONS AND WASTE STREAM IDENTIFICATION FOR THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282

There are two major groups of processes used in SIC 282: polymerization and spinning. Because polymerization processes are similar for all segments of this industry, the SIC Classification framework for the discussion presented below is not maintained. Instead, these topics are presented in a manner more descriptive of the actual conditions in the industry.

The section is organized as follows:

- General description of the polymerization process to provide a technical framework for the understanding of the individual processes.
- General description and quantification of waste stream factors.
- Specific, more detailed description of the processes and waste streams. This description is subdivided into several parts so that the various aspects of SIC 282 are covered in a logical format. In particular, regarding plastic resins and synthetic rubber, the discussion addresses itself to:
    - Processes and waste streams associated with olefinic polymers
    - Processes and waste streams associated with the non-olefinic polymers used in man-made non-cellulosic fiber manufacture
    - Process and waste streams associated with the principal other non-olefinic polymers
    - Processes and waste streams associated with the production of man-made cellulosic polymers
    - Processes and waste stream associated with the spinning operations.

Note that for the purposes of this study the term olefinic polymer refers to those polymers where the main linkage generally occurs at a carbon-carbon double bond site.

3.1 Introduction

This section provides a general description of the polymerization process and of the waste streams generated.

The rationale for this approach is that there exist fundamental similarities among most of the polymerization processes. However, this section does not discuss the processes involved in the production of cellulosic man-made polymers nor the various spinning processes which are discussed separately in the last paragraphs of the following section. This is because:

- Cellulosic man-made polymers are prepared by different methods from the production of the other synthetic polymers (albeit often at the same production sites).
- Spinning operations are a different technology from polymerization.

3.1.1 General Description of the Polymerization Process

In general, polymerization is the linking together of single molecules (monomer) to form repeating units of one or several molecular species. Two problems of the polymerization process are:

- The efficient removal of the considerable amount of heat generated in the process of polymerization.
- The change of phase to an extremely viscous or even solid material of a liquid or gaseous monomer.

These two problems are usually solved simultaneously by providing a carrier fluid for the final product. In most instances, this carrier fluid is water; in which case the processes are described as emulsion or suspension polymerization. When the carrier fluid is not water, it can be an organic solvent. In this case, the process is known as solution polymerization. Another approach is that of using an excess monomer acting as a solvent. These processes are known as bulk polymerization.

The above processes can be run batchwise, semicontinuously or continuously.

Pressures involved in the reactions may vary from near atmospheric to thousands of atmospheres (40,000 p.s.i.). Temperatures may range from near room temperature, $20^{o}C$ ($70^{o}F$) to $175^{o}C$ ($300^{o}F$). Catalysts or initiators may be involved. However, in most cases they are consumed in the process or are incorporated in the final product. Spent catalysts may sometimes become part of the waste stream.

The following steps that are common to most processes have been previously listed on p. II-8 and include:

- Monomer(s) storage
- Monomer(s) feeding to the reactor
- Carrier feeding to the reactor (except for bulk processes)
- Catalyst feeding to the reactor
- Reaction
- Monomer(s) recovery
- When required, carrier recovery
- Processing of the polymer.

These steps and their interactions are presented in Figure II-1.

In some instances it is necessary to condition the monomer by removing the inhibitor.

Most facilities produce hundreds of millions of pounds per year. However, about 10% of the total production is carried out in extremely small scale operations, i.e., several thousand pounds per year.

Tables II-35 and II-36 summarize the production elements for the major plastics and synthetic rubbers, respectively.

3.1.2 General Description Of The Waste Streams From Polymerization

The waste streams produced in polymerization are described next. There are six major classes of waste streams.

Table II-35

SUMMARY OF PRODUCTION ELEMENTS IN THE PLASTIC RESINS INDUSTRY — SIC 2821

Product	Process	Carrier Fluid	Monomer(s)	Initiator or Catalyst$^{(1)}$	Additives
Polyethylene					
Low Density	Modified Bulk		Ethylene$^{(2)}$	Organic peroxides	
High Density	Solvent	Solvent (60-90°C B.P.)	Ethylene$^{(2)}$	Ziegler/Phillips$^{(3)}$	
Polyvinyl Chloride	Suspension/Emulsion	Water	VCM	Lauroyl peroxide azobisisobutyronitrile	Polyvinyl alcohol, gelatin, methylcellulose
	Bulk	None	VCM	(same)	Proprietary (if any)
Polystyrene	Suspension	Water	Styrene	Lauroyl peroxide azobisisobutyronitrile	Tricalcium phosphate, surfactants, dyes
	Bulk/Solution	Ethylbenzene	Styrene	Benzoyl peroxide Butyl perbenzoate	
ABS-SAN	Emulsion	Water	Acrylonitrile, butadiene, styrene	Peroxides	Carbon tetrachloride, shortstop (hydroquinine) pigments, plasticizers
Polypropylene	Solution	Heptane, cyclohexane xylene	Propylene	Ziegler (Al, Ti)	Antioxidants, fillers, plasticizers, antistats
Phenolics	Emulsion	Water$^{(4)}$	Formaldehyde (37%) phenol and substituted phenols	Alkalies or Acids	Solvents, oils, plasticizers, wood flour, other resins, e.g. amino resins
Polyesters$^{(5)}$	Mass	None	Polyalcohols, dibasic acid or anhydride	Acetates of cobalt, manganese or cadmium	Styrene, hydroquinone
Alkyds	Fusion (mass) Solvent (solution)	None Xylene, mineral spirits	Phthalic anhydride Fatty acids, oils, glycols, polybasic acids	None	
Acrylics	Emulsion/Suspension	Water	Acrylates	Emulsifiers, persulfates	Reducing agents, ferric ammonium sulfate
	Solvent	Various solvents	Acrylates		
	Bulk	Monomer	Methyl methacrylate	Peroxides	
Polyamides					
Nylon 6,6	Suspension	Water	Hexamethylene diamine	None	Acetic acid, TiO$_2$, spin finishes
Nylon 6	Suspension	Water	Caprolactam	Nylon 6,6 or ω amino caproic acid	Acetic acid, TiO$_2$, spin finishes

ABS-SAN = Acrylonitrile butadiene styrene-Styrene acrylonitrile

---

(1) The terms catalyst and initiator are used somewhat interchangeably, in polymerization. Initiators are, by definition, used up in the reaction and their decomposition products are usually discharged with the polymer. Catalysts are seldom separated at the end of the reaction.

(2) Copolymerization is frequent (a current comonomer may be vinyl acetate).

(3) Ziegler catalysts = Isopropyl or isobutyl hydrides -- Phillips A ceramic type chromium oxide, aluminum oxide finely divided solid.

(4) The water is supplied from the use of a water solution of formaldehyde (Formalin 37%)

(5) The bulk of the production is for fiber and is often carried out in fiber plants (SIC 2824).

Source Foster D. Snell, Inc. analysis of industry interviews and literature information.

Table II-36

SUMMARY OF PRODUCTION ELEMENTS IN THE
SYNTHETIC RUBBER INDUSTRY —
SIC 2822

Product	Process	Carrier Fluid	Monomer(s)	Catalyst	Additives
SBR Latex	Emulsion	Water	Styrene, Butadiene	Peroxides	Soap, Fe or K salts, Dodecyl-Mercaptan, Hydroquinone
SBR Crumb	Emulsion	Water	Styrene, Butadiene	Peroxides	Soap, Fe or K Salts, Dodecyl-Mercaptan, Hydroquinone
SBR Masterbatch	Emulsion	Water	Styrene, Butadiene	Peroxides	Carbon Black, Soap, Extender Oil, Dodecyl-Mercaptan, Fe or K Salts, Hydroquinone
SBR Oil Extended	Solution	Hydrocarbon Solvent	Styrene, Butadiene	Lithium Alkyls	Extender Oils Proprietary (ethers?)
SBR Crumb	Solution	Hydrocarbon Solvent	Styrene, Butadiene	Lithium Alkyls	Proprietary (ethers?)
Polybutadiene	Solution	Hydrocarbon Solvent	Butadiene	Titanium, Vanadium, Zirconium Halides, (K) Aluminum Alkyls	Proprietary
Polyisoprene	Solution	Hydrocarbon Solvent	Isoprene	Aluminum Trialkyl Titanium Tetrachloride	Proprietary (can be oil extended)
Butyl and Chlorobutyl Rubber	Solution	Methyl Chloride Hexane	Isobutylene/Isoprene	Aluminum Chloride	Calcium Stearate, Antioxidant, Chlorine Gas (for chlorobutyl)
Neoprene	Emulsion	Water	Chloroprene	Potassium Peroxydisulfate (K), Sulfur	Naphthalene Sulfonic Acid, Formaldehyde, Soap, Tetraethylthiuram Disulfide
EPM and EPDM	Solution	Hydrocarbon Solvent	Ethylene-Propylene Ethylidene, Norbornene	Vanadium Oxychloride, Aluminum Alkylchlorides	Stabilizer and antioxidant (Proprietary)

Sources: (R) M. Morton, "Rubber Technology", Second Edition, Van Nostrand (1973). Except where noted.
(K) Kirk Othmer, "Encyclopedia of Chemical Technology", Second Edition, Interscience (1964).

3.1.2.1 Off-Grade Products

The main waste stream, in these processes, consists of off-grade products. The reasons are production upsets, product changes, mechanical failures and abrasion in handling.

3.1.2.2 Still Bottoms

This stream originates in monomer or solvent recovery. It is composed of high boiling residues called still bottoms, which are separated in the distillation process. These residues consist of relatively low molecular weight, shortchain polymerized material and other organic products resulting from chemical degradation of product or solvent.

3.1.2.3 Spent Adsorbents And Filters

Granular or pulverulent material (adsorbent) is used to condition the monomer by removing traces of water. This material is eventually discarded, and, together with the filter elements used from its separation from the production stream, constitutes a significant solid waste stream.

3.1.2.4 Spent Catalysts

In some processes, spent catalyst constitutes a separate waste stream. In this industry, in many cases, the catalyst is allowed to remain in the finished product and thus does not constitute a waste stream. In other cases, the catalyst goes to the wastewater treatment facility and becomes part of the sludge.

3.1.2.5 Waste Oils

There are two sources of waste oils:

- Spillage from gear boxes and bearings of rotating equipment
- Oil changes.

The spillage usually finds its way to run-off sewers or floor drains. If spillage at a plant is significant, traps are provided to collect the waste oil. Spent lubricating oils are generally collected in drums.

3.1.2.6 Wastewater Treatment Sludges

The plants in which most of the polymerization processes are carried out have usually some form of treatment facilities for their wastewaters. The contribution of the polymerization processes does not constitue, in the majority of cases, the bulk or even a major portion of the wastewater loads. This is due to the fact that at most plant locations other processes are carried out which require large quantities of process water, and which are more likely to contaminate the water with undesirable components.

The treatment of wastewater generated in chemical plants usually involve at least a clarification step.

Clarification may be preceeded by such steps as pH adjustment and/or the addition of flocculant or coagulant. Clarification produces a sludge which may contain solids from the polymerization process. In addition to the catalysts discussed in the previous paragraph, the primary sludges may also contain fines from the polymerization processes.

In addition, there may be a secondary treatment operation in which soluble contaminants (e.g., alcohols) from the polymerization are oxidized biologically and produce a biological sludge.

Because SIC 282 plants are usually part of large chemical complexes, the contribution of the polymerization processes to the total wastewater load is minor.

3.2 Detailed Process Descriptions

In this section, the various processes used to manufacture the subject polymers are discussed in more detail. Although many classifications and segmentations are valid, the general framework for the discussion is based on a segregation of the processes into five groups. The first four groups cover the processes used in the manufacture of the polymers, while the last group addresses itself to the spinning.

In view of processing commonalities, the first group of processes discussed contains those used for what we call the olefinic polymers. This group encompasses most of the major polymers derived from olefinic materials, with the addition of vinyl chloride and acrylonitrile. The group encompasses all the major synthetic elastomers and the other major resins (i.e., polypropylene, polyethylene, styrene butadiene rubber).

A second group consists of the three classes of polymers used in the non-cellulosic fiber industry. These are less directly related to the petrochemical industry because the monomers involved are produced in chemical plants (i.e., acrylics, polyesters).

A third group consists of other non-olefinic resins, usually manufactured by batch processes. In terms of volume of production, this group is dominated by the phenolics and amino resins (i.e., phenolics, epoxies, alkyd resins).

The fourth group comprises the cellulosic man-made (or man-modified) polymers (i.e., rayons and acetates).

3.2.1 Processes And Waste Streams Associated With The Production Of Olefinic Polymers

The types of polymers included in this group are as follows:

- Styrene Butadiene Rubber (SBR)
- Polyethylene: low and high density
- Polyvinyl Chloride and Polyvinyl Acetate
- Polystyrene and other styrene resins (ABS* and SAN**)
- Polybutadiene
- Polypropylene
- Neoprene
- EPM-EPDM Rubbers
- Polybutenes and Copolymers.

Table II-37 illustrates the waste factors associated with the above olefinic polymers.

The processes used include:

- Emulsion and suspension polymerization
- Mass or bulk polymerization
- Solution polymerization.

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* ABS= Acrylonitrile butadiene styrene

** SAN= Styrene acrylontrile

TABLE II-37

ESTIMATED WASTE FACTORS ASSOCIATED WITH THE PRODUCTION OF OLEFINIC POLYMERS AS A PERCENT OF TOTAL PRODUCTION-- SIC 282

Product	Production	Estimated Waste Factors (% of Total Production)			
	(KKKg/Yr.)	Off-Grade Products	Still Bottoms and Waste Oils	Other	
Styrene Butadiene Rubber (SBR)	2,216	2.5	1.15	Wastewater Sludge	1.3
Polyethylene	4,018	-	-	-	
Low Density	-	1.0	1.00	N.A.	
High Density	-	0.3	0.05	Spent Adsorbent and Catalyst	Less than 0.1
Vinyl Resins	2,277	-	-	-	
Chloride	-	2.0	N.A.	Wastewater Sludge	1.1
Acetate	-	1.0	0.1	N.A.	
Styrene Resins	2,244	-	-	-	
Polystyrene	-	0.2	1.0	N.A.	
ABS-SAN	-	2.0	0.5	Wastewater Sludge	1.0
Polybutadiene	477	0.2	0.01	Spent Adsorbent	0.01
Polypropylene	2,196	0.5	1.0	Wastewater Sludge (Dry) Nitrile waste	0.20 0.05
Neoprene	177	3.0	6.0	N.A.	
EPM-EPDM Rubbers	163	None Reported	None Reported	Spent Adsorbent and Catalyst	Less than 0.1

ABS = Acrylonitrile butadiene styrene
N.A. = Not Applicable
SAN= Styrene acrylontrile

Source: Foster D. Snell, Inc.

A series of figures are provided to illustrate the processes and waste streams discussed under olefinic polymer.

- Figure II-2 -- Emulsion/Suspension Polymerization
- Figure II-3 -- Bulk or Mass Polymerization
- Figure II-4 -- Solution Polymerization, Phillips Process
- Figure II-5 -- Solution Polymerization, Ziegler Process
- Figure II-6 -- Particle Form Polymerization

3.2.1.1 Emulsion And Suspension Polymerization

Figure II-2 presents a flow diagram of a typical emulsion/suspension polymerization process. The wastes include:

- Off-grade products--fines and scrap pellets
- Still bottoms--polymer waste
- Wastewater sludges.

A large number of polymers are manufactured by processes in which the monomer is dispersed in an aqueous, continuous phase during the course of the reaction. There are technical differences between emulsion and suspension systems which pertain to the polymerization reaction itself, but do not have a bearing on the waste production. Therefore, both methods are covered by this discussion.

Batch processes are commonly used. Typical reactor size is 18.9 to 113.5 m^3 (5,000 to 30,000 gal.). The batch cycle consists of the continuous introduction of a water-monomer emulsion with agitation. Polymerization occurs at about the rate of monomer addition; the heat of reaction is removed by cooling tower water circulated through the jacket. The reactor is vented through a condenser for monomer recovery; and the condensate, including any water, is returned directly to the vessel. On completion of the batch, a short "soaking" time is allowed for completion of the reaction, and water is then added to dilute to the desired end composition. The batch is drawn off through a screen to product storage. Oversize screenings constitute a waste stream.

A number of products, polyvinyl acetate for example, are marketed in latex form with no further processing required. When the product is isolated and sold in solid form, the screen latex is pumped to another tank where it is coagulated. The liquid phase is separated by centrifugation or filtration and the cake is dried.

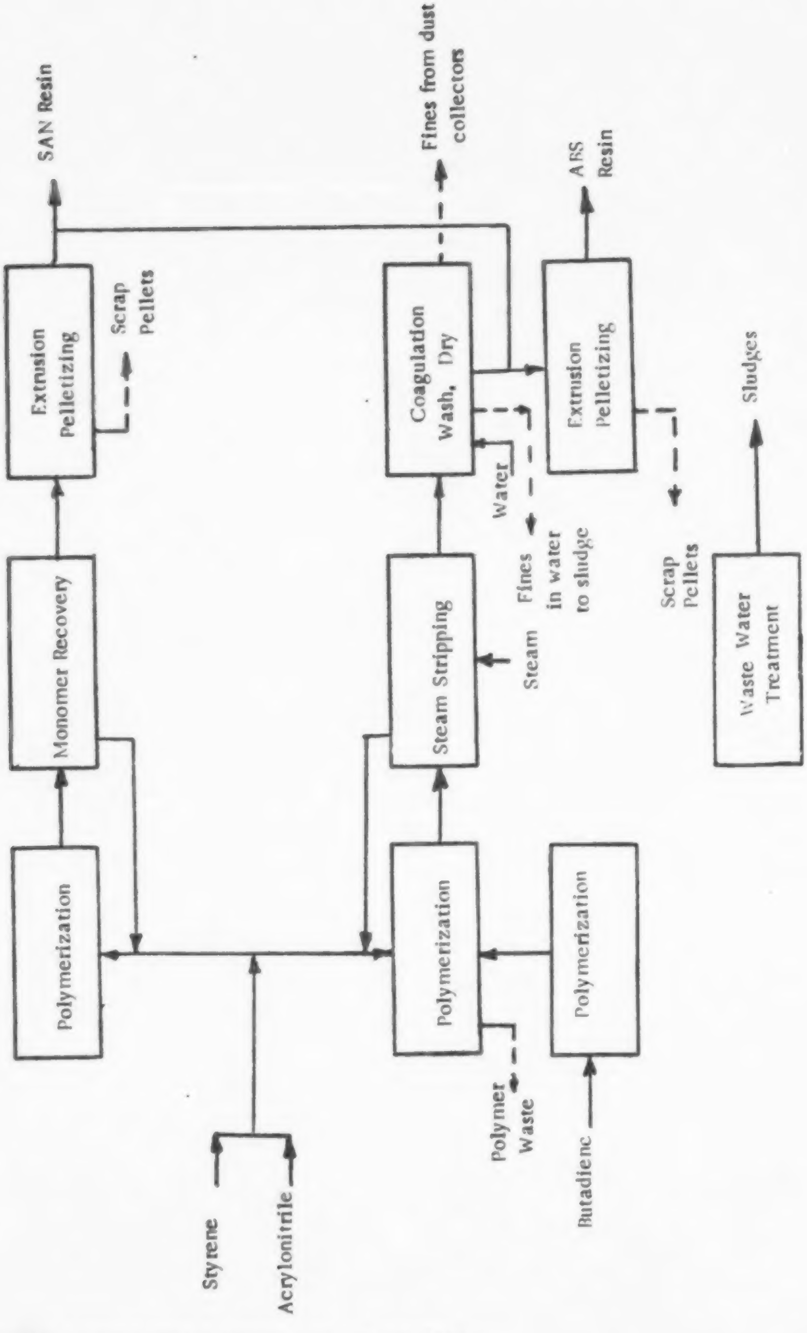
Styrene
Acrylonitrile
Polymerization
Monomer Recovery
Extrusion Pelletizing
Scrap Pellets
SAN Resin
Polymerization
Steam Stripping
Steam
Coagulation Wash, Dry
Water
Fines in water to sludge
Fines from dust collectors
Extrusion Pelletizing
ABS Resin
Scrap Pellets
Polymer Waste
Butadiene
Polymerization
Waste Water Treatment
Sludges

FIGURE II-2
EMULSION/SUSPENSION POLYMERIZATION FLOW DIAGRAM

Source: Environmental Protection Agency Study (Contract No. 68-01-0030)

The emulsion process is probably the most important in polymer manufacture. It is used in particular in the production of the following olefinic polymers:

- Styrene-butadiene rubber (SBR)*
- Polystyrene
- Acrylonitrile butadiene styrene (ABS)
- Styrene acrylonitrile (SAN)
- Polyvinyl chloride (PVC)*
- Polyvinyl acetate (PVAC)
- Neoprene.

3.2.1.2 Mass Or Bulk Polymerization

In these processes, an excess of the monomer is used as the diluent or carrier fluid. There are two types of processes:

- Low pressure polymerization
- High pressure polymerization.

Figure II-3 presents a typical bulk or mass polymerization flow diagram.

3.2.1.2.1 Atmospheric Or Low Pressure Mass Polymerization

A number of important polymers are manufactured by mass polymerization, a system in which the purified monomer is allowed to polymerize under controlled conditions of temperature and reaction rate. Catalysts and modifiers are used to initiate the reaction, control its rate, and influence the final molecular weight. These materials are used in very small quantities, and their residue remains in the product. Removal of the heat of reaction is a difficult problem in this process and limits the type of equipment which can be used.

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* A substantial production of these polymers is carried out also by other processes, e.g., solution or mass (or bulk) polymerization.

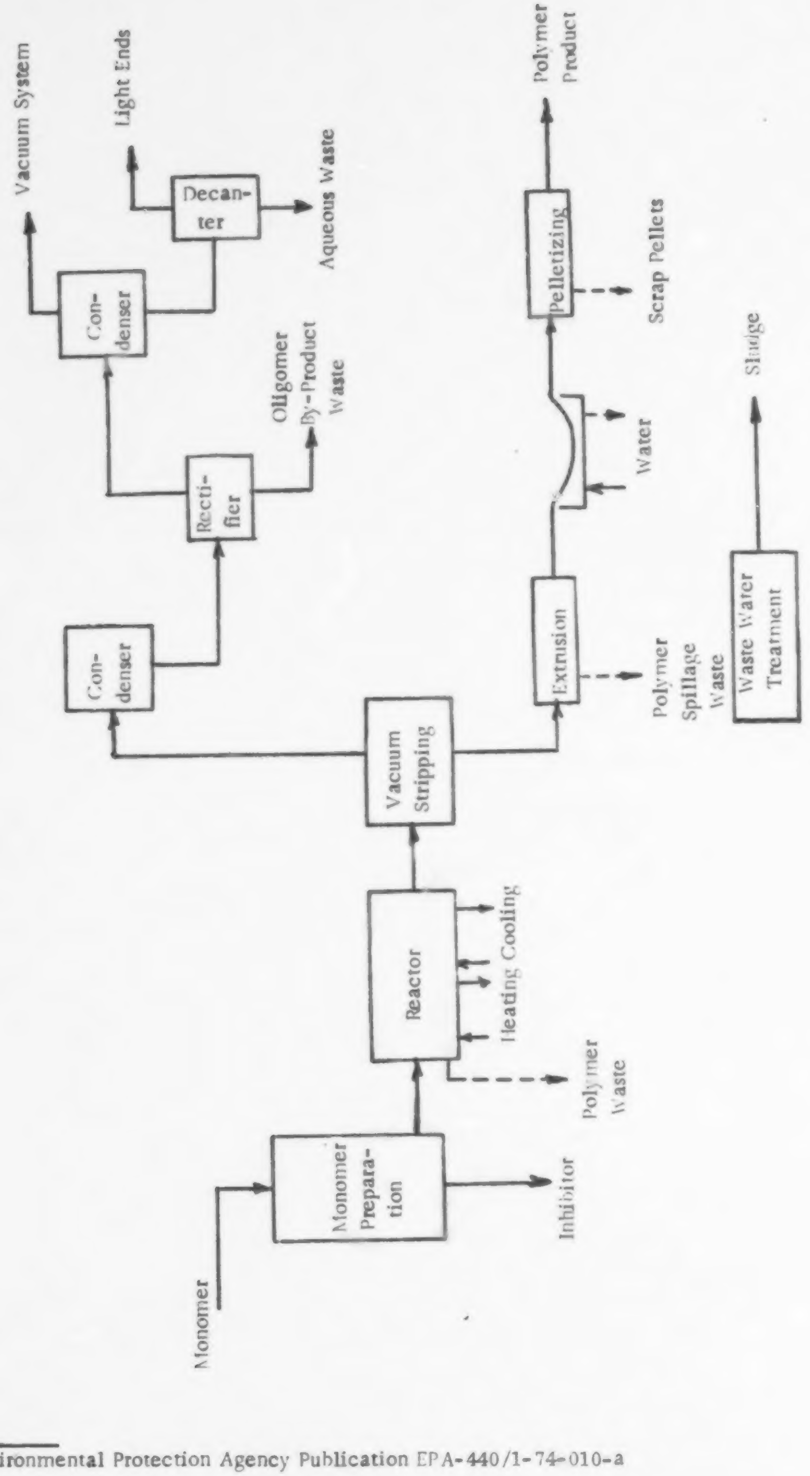

Monomer
Monomer Preparation
Inhibitor
Reactor
Polymer Waste
Heating Cooling
Vacuum Stripping
Condenser
Rectifier
Oligomer By-Product Waste
Condenser
Vacuum System
Decanter
Light Ends
Aqueous Waste
Extrusion
Polymer Spillage Waste
Water
Pelletizing
Scrap Pellets
Polymer Product
Waste Water Treatment
Sludge

FIGURE II-3
EPA
BULK OR MASS POLYMERIZATION FLOW DIAGRAM

Source: Environmental Protection Agency Publication EPA-440/1-74-010-a

It is usually necessary to protect the purified monomers from autopolymerization in storage. The inhibitor used for this purpose is removed by monomer preparation. The reaction system is usually continuous, or multi-stage, and the first step is to bring the monomer to reaction temperature by indirect heating. A heat-transfer oil or fluid, such as Dowtherm, circulated from a fired heater, is used. Once reaction begins, the heat is removed by transfer to cooling oil circulated through coils or in a jacket. The circulated oil is cooled by water in conventional heat-exchange equipment.

On leaving the reactor, the polymer contains unreacted monomer and small amounts of contaminants and by-products. These materials are removed by vacuum stripping. The recovered monomer is then treated in a rectifier. The contaminants and by-products constitute the oligomer by-product waste (still bottoms). Pure polymer is forced through extrusion to make strands of polymer, which are cooled in a water bath before pelletizing for storage and shipment.

Other wastes include off-grade product, polymer waste and scrap pellets.

Products of this process include:

- Polystyrene (PS)
- Acrylonitrile, butadiene, styrene (ABS)
- Styrene, acrylonitrile (SAN)
- Polyvinyl chloride (PVC).

3.2.1.2.2 High Pressure Mass Polymerization

This process is mainly used for the manufacture of low density polyethylene.

Ethylene gas is mixed with a very small quantity of air or oxygenated organic compounds as a catalyst and with recycled ethylene, and raised to high pressure in reciprocating compressors.

The operating pressure is considered to be confidential information, but the trend in the industry has been to the highest practical pressures, and literature references to design ratings of 40,000 psi (2,722 atm) and up are common. At the operating pressure and at an appropriate temperature, polymerization is carried out in jacketed tubular reactors. The heat of reaction is removed to hot water in the jacket, which circulates through a waste heat boiler for the generation of steam.

On completion of the reaction, the pressure is reduced and polymer meeting the specified properties is separated in flash drums. This molten material is pumped through a multiple orifice extruder to an underwater chiller and chopper to produce polyethylene pellets. A purge stream of this water is removed and replaced with high-quality, clean water. The purge is at a rate sufficient to remove polymer fines generated in chipping. The quantity of fines depends on the grade of polymer produced and with some grades is negligible. Wet polymer from the screen is dried and stored in silos.

The waste factors in the production of low density polyethylene consist mainly of off-grade products (1% of total production) and still bottoms and waste oils (1% of total production).

3.2.1.3 Solution Polymerization

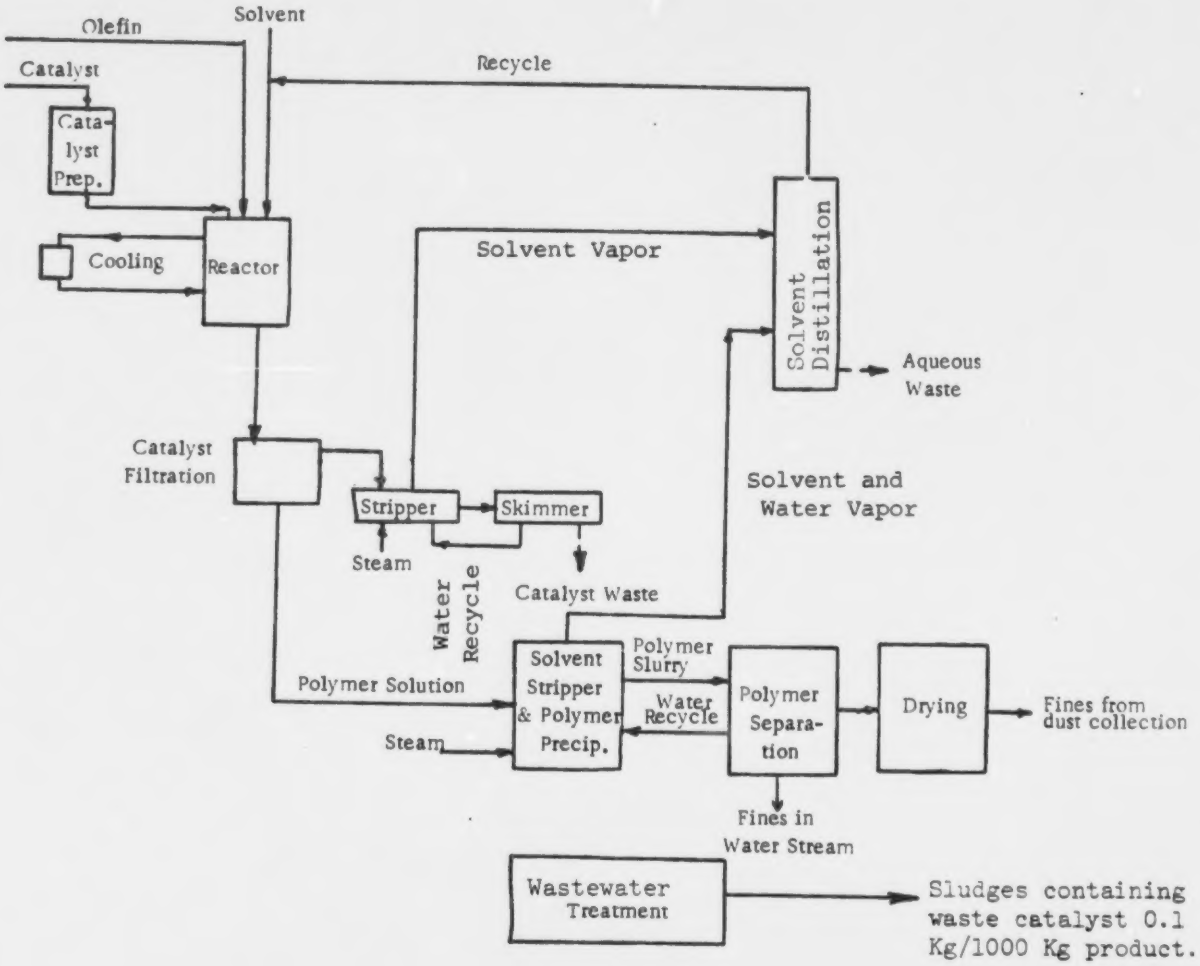
There are two main variants of this process, basically depending on the type of catalyst used. The Phillips processes use a chromium oxide or alumina type of catalyst and the Ziegler processes use metal alkyd catalyst. A recent variant of these processes is called the particle form process.

3.2.1.3.1 Solution Polymerization (Phillips Processes)

In this process (Figure II-4), the polymer is dissolved in the reaction solvent as it is formed, and the catalyst is present as a separate solid phase. The catalyst system is activated chromium oxide deposited on a carrier, such as alumina.

FIGURE II-4

SOLUTION POLYMERIZATION
(PHILLIPS PROCESS)


Olefin
Solvent
Catalyst
Recycle
Catalyst Prep.
Cooling
Reactor
Solvent Vapor
Solvent Distillation
Aqueous Waste
Catalyst Filtration
Stripper
Skimmer
Steam
Catalyst Waste
Water Recycle
Solvent and Water Vapor
Polymer Solution
Solvent Stripper & Polymer Precip.
Polymer Slurry
Water Recycle
Polymer Separation
Drying
Fines from dust collection
Steam
Fines in Water Stream
Wastewater Treatment
Sludges containing waste catalyst 0.1 Kg/1000 Kg product.

Source: EPA publication EPA-440/1-74-010-a

As the concentration of polymer, or the molecular weight of the polymer in solution increases, the viscosity of the solution also increases markedly. This phenomenon places severe limitations on the processability of the reaction mass. Temperature control is accomplished by indirect cooling with refrigerated water, and the viscosity must not be allowed to exceed a reasonable limit for efficient heat transfer.

Viscosity is also an important limitation in the next step, which is the removal of the catalyst by filtration. From the filter, the catalyst, wet with solvent, is mixed with hot water and the solvent removed by steam stripping. Solvent-free catalyst slurry is processed in a skimmer and solid catalyst is produced as a waste.

The water is recycled to the steam solvent stripper. Vapor from the steam stripper is combined with other recovered solvent for purification by solvent distillation.

The catalyst-free polymer solution is processed in a system which precipitates the polymer, and then removes the last traces of solvent by steam stripping, leaving the polymer as a slurry in water. The polymer water slurry goes to polymerization, and the filtrate is recycled to the stripper.

Recovered solvent and vapors from the steam strippers are processed by the solvent distillation system.

Dry polymer crumb or flake is blended, melted, extruded and pelletized. This pelletizing operation is carried out under water, with cooling and transport accomplished with recirculated, clean, softened water. A purge stream amounting to a few percent of the circulation rate is withdrawn to waste. This system is the same as that already described for the low density polyethylene process.

The principal product of this process is high density polyethylene. However, the process is also used for some copolymers in this family of products.

3.2.1.3.2 Solution Polymerization (Ziegler Processes)

This process (Figure II-5) depends on a catalyst system discovered and patented by Dr. Karl Ziegler. There have been a number of improvements by companies using the basic principle, and the name in fact applies to the catalyst system. Each user has had to design his own plant. However, it is convenient to group under this name all polyolefin processes which employ a reaction solvent in which the polymer precipitates as it is formed. The catalyst is a relatively complex alkyl, or alkyl halide, of metals such as titanium and aluminum.

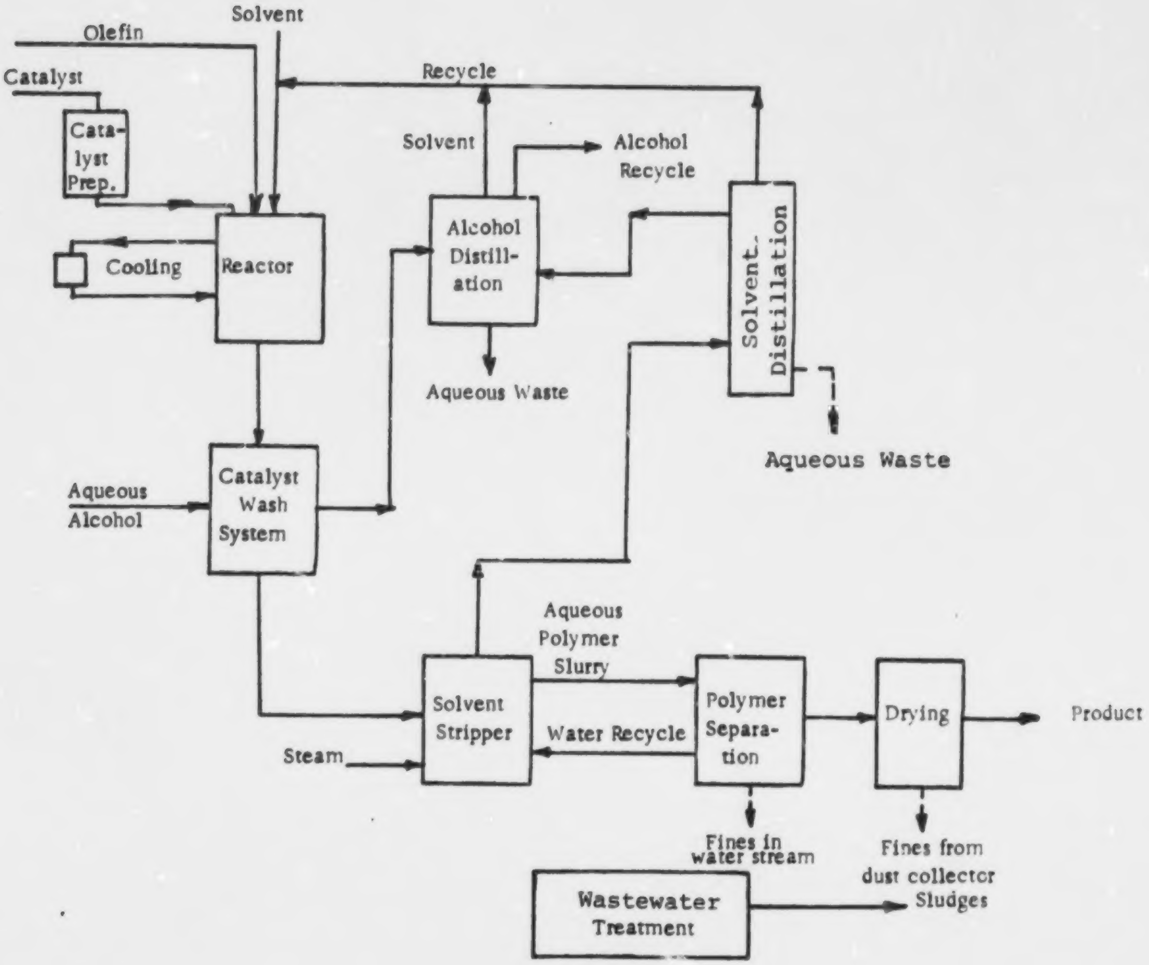
Catalyst preparation, monomer addition, and reaction proceed as for the solution process described in 3.2.1.3.1. Temperatures and pressures are lower; and, because the polymer does not dissolve, problems caused by excessive viscosity do not arise.

The next step is the removal of the catalyst, which historically has been the most troublesome part of the system. The residual catalyst content of the final polymer must be very low, and for this reason a system is employed which allows transfer of catalyst to a separate liquid phase. Aqueous alcohol is used for this purpose and the catalyst is removed in solution, leaving the polymer slurried in the hydrocarbon solvent.

The aqueous alcohol phase is treated to precipitate the catalyst as the oxides (e.g., titanium, aluminum), and these materials eventually appear as finely-divided suspended solids in the aqueous waste. They will settle sufficiently to permit discharge of a clarified effluent. Together with very fine product waste, these oxides constitute the bulk of the sludge from the waste treatment plant. This amount to 0.1 Kg per 1000 Kg of product.

Alcohol is recovered for reuse by distillation. The aqueous phase remaining is the principal waste product of the plant.

FIGURE II-5
SOLUTION POLYMERIZATION
(ZIEGLER PROCESS)



Olefin
Solvent
Catalyst
Catalyst Prep.
Recycle
Solvent
Alcohol Recycle
Reactor
Cooling
Alcohol Distillation
Solvent Distillation
Aqueous Waste
Aqueous Waste
Aqueous Alcohol
Catalyst Wash System
Aqueous Polymer Slurry
Solvent Stripper
Water Recycle
Polymer Separation
Drying
Product
Steam
Fines in water stream
Fines from dust collector
Sludges
Wastewater Treatment

Source: EPA publication EPA-440/1-74-010-a

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The polymer slurry is processed by steam stripping, filtration, drying, extruding and pelletizing as is done for the solution process, and the hydrocarbon solvent is purified by distillation. A small quantity of aqueous waste is recycled to the alcohol unit.

Products obtained by this process include:

- High Density Polyethylene
- Styrene Butadiene Rubber (SBR)
- Polybutadiene
- EPM-EPDM Rubber
- Butyl and Chlorobutyl Rubber
- Polypropylene
- Polybutene
- Copolymers of this family of monomers.

3.2.1.3.3 Particle Form Process

The problems of the solution process for polyolefins have to a large degree been overcome in a newer version called the particle form process, and the method has a growing commercial acceptance for the manufacture of high density polyethylene, polypropylene and copolymers (Figure II-6). There have been three major changes:

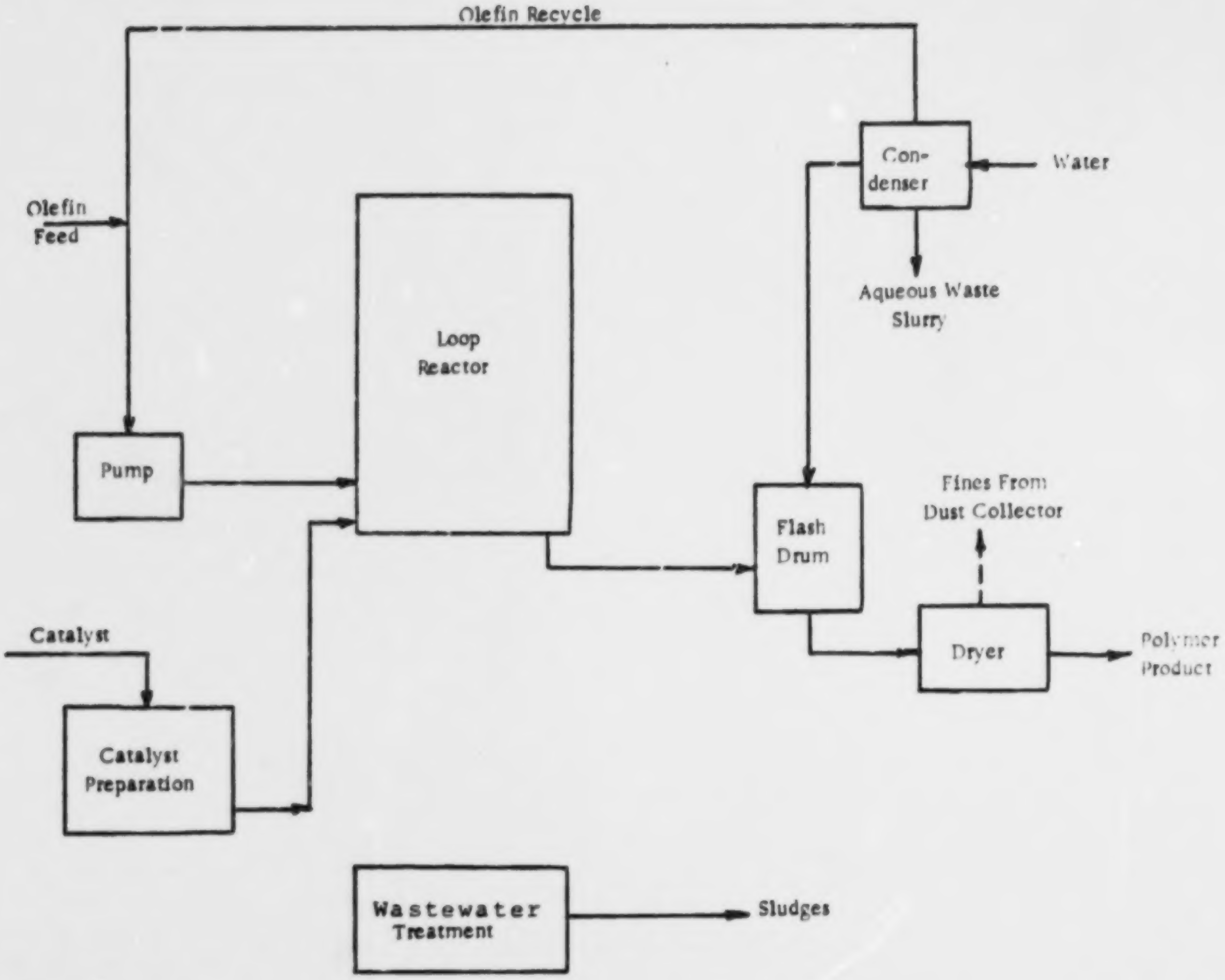
- The catalyst (ethylene and comonomer) system has been modified so that it can be incorporated into the polymer. Its activity has been increased to the point that special measures for catalyst removal are unnecessary for many grades of polymer.

- The hydrocarbon solvent system has been modified so that the polymer is not as soluble and is obtained as a slurry rather than a solution in the diluent.

- Special design loop-reactors have been developed which allow the polymerization system to operate under good control of reaction conditions and at satisfactory rate.

FIGURE II-6

PARTICLE FORM POLYMERIZATION FLOW DIAGRAM


Olefin Recycle
Con-denser
Water
Olefin Feed
Aqueous Waste Slurry
Loop Reactor
Pump
Fines From Dust Collector
Flash Drum
Catalyst
Dryer
Polymer Product
Catalyst Preparation
Wastewater Treatment
Sludges

Source EPA publication EPA-440/1-74-010-a

In this method, catalyst and olefin feed are added to the reaction mass which is circulated continuously through the loop reactors. A stream is also withdrawn continuously from the reactor to a flash drum. Polymer is removed from the bottom of the flash drum, dried, and processed through an extruder pelletizer as with the other methods.

The vapor stream from the flash drum is scrubbed to remove polymer fines. This step produces a small quantity of wastewater. Both unreacted olefin and recovered diluent are then separated from the overhead stream and recycled to the reaction step.

The products and waste streams of these processes are essentially the same as reported previously (3.2.1.3.1 and 3.2.1.3.2).

3.2.2 Non-Olefinic Polymers Used In Fiber Manufacture

There are three main groups of polymers that are used in non-cellulosic fiber manufacture: acrylics and modacrylics, polyamides (nylons) and polyesters. Olefinic polymers are also used in the manufacture of fibers (in particular polypropylene) but the production of these has already been described. The spinning methods are described in Section 3.2.5.

A series of figures are provided to illustrate the processes and waste streams discussed under non-olefinic polymers used in fiber manufacture.

- Figure II-7 -- Acrylic and Modacrylic
- Figure II-8 -- Nylon "6" (Polyamide)
- Figure II-9 -- Nylon "6,6" (Polyamide)
- Figure II-10 -- Polyester Resin

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3.2.2.1 Acrylics and Modacrylics

The bulk of this production is carried out by a suspension or emulsion process (Figure II-7). The monomer acrylonitrile, together with comonomers such as vinyl chloride(1) are added to a reactor kettle at a ratio of about 10 parts of water to one part of monomer. The reaction is initiated by redox catalysts and initiators such as ammonium perdisulfate, sodium metabisulfite and sulfuric acid. The common practice is to meter the reactants and water continuously into the reactor and to obtain the polymerized material as an emulsion overflowing out of the reactor. The emulsion is filtered continuously to remove large size agglomerates (gels or "fish eyes").

The filtered material is directed to monomer recovery where the free monomer is stripped and returned to the reactor. The stripped suspension is then separated by centrifugation, followed by a water wash, dried in a continous oven and stored for sale to other processors or for captive use. The precatalyst is recovered. Generally, in multi-plant operations by a given company, one polymerization facility services the various spinning plants.

The most important source of wastes is the filtering process. The waste stream consists of the polymer itself, sometimes contaminated with unreacted comonomer.

The monomer recovery still bottoms are essentially water based and are disposed to wastewater treatment facilities. They contain low molecular weight polymer, estimated at 7 kg per 1000 kg produced.

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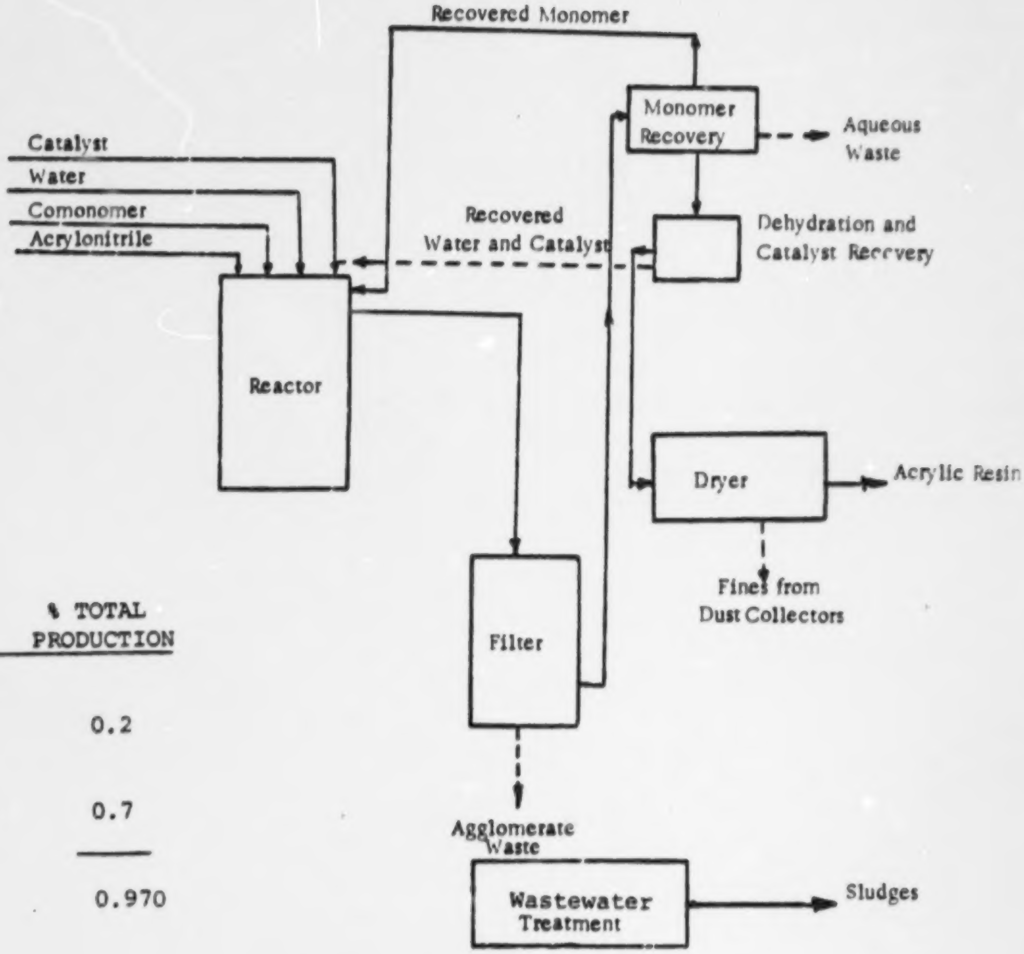
(1) Kirk-Othmer, Encyclopedia of Chemical Technology (2nd Ed.), Volume I, P. 333, Interscience Publishers, New York (1963).

FIGURE II-7

ACRYLIC AND MODACRYLIC FLOW DIAGRAM


Recovered Monomer
Monomer Recovery
Aqueous Waste
Catalyst
Water
Comonomer
Acrylonitrile
Recovered Water and Catalyst
Dehydration and Catalyst Recovery
Reactor
Dryer
Acrylic Resin
Fines from Dust Collectors
Filter
Agglomerate Waste
Wastewater Treatment
Sludges

MAJOR SOLID WASTES	% TOTAL PRODUCTION
Offgrade Products	0.2
Still Bottoms and Waste Oils	0.7
Total	0.970

Source: EPA publication EPA-440/1-74-010-a

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3.2.2.2 Polyamides

There are two main polyamide resins used in fiber production; Nylon 6 and Nylon 6,6 (Figures II-8 and II-9). Nylon 6 is essentially a polymer of caprolactam, and Nylon 6,6 results from the condensation of hexamethylene diamine and adipic acid, which are reacted to form nylon salt.

There are two ways to polymerize Nylon 6. They differ essentially in how the unreacted caprolactam monomer is removed. In the wet method, polymerized chips are washed with water and the resulting caprolactam solution is eventually concentrated, after treatment with potassium permanganate, to a 70 percent solution. This final solution is separated into a bottom stream containing solid oligomers and high boiling liquids and reasonably pure caprolactam which is returned to process. Two solid waste streams are produced: the permanganate residue which is in the form of a solid and the still bottoms.

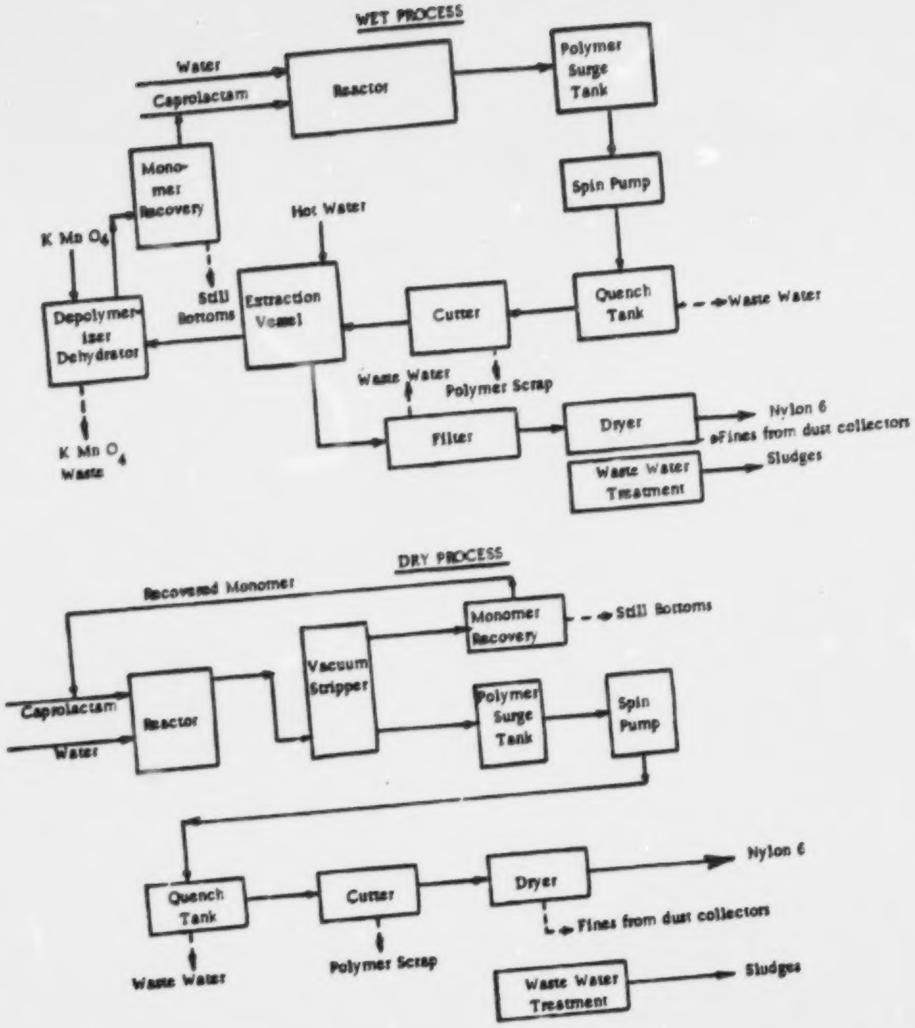
In the second, or dry process, the unreacted caprolactam is stripped from the molten polymer under vacuum. In this process, no waste stream is produced, except for equipment cleanings and ends of run.

To make Nylon 6,6, hexamethylene diamine is reacted with adipic acid to give a nylon salt solution which is decolorized with adsorbent charcoal. The salt is then mixed with water and acetic acid and polymerized in an autoclave with addition of delusterant (titanium dioxide). The resin is then band cast, chopped, blended and stored for shipment or local use in spinning operations.

A significant waste stream consists of a filter cake, which is a mixture of spent carbon, diatomaccous earth and nylon salt from the decolorizing operation, It amounts to 0.36 percent of the total production. Some of the wastewater streams from the pro-

FIGURE II-8

NYLON 6 (POLYAMIDE) FLOW DIAGRAM

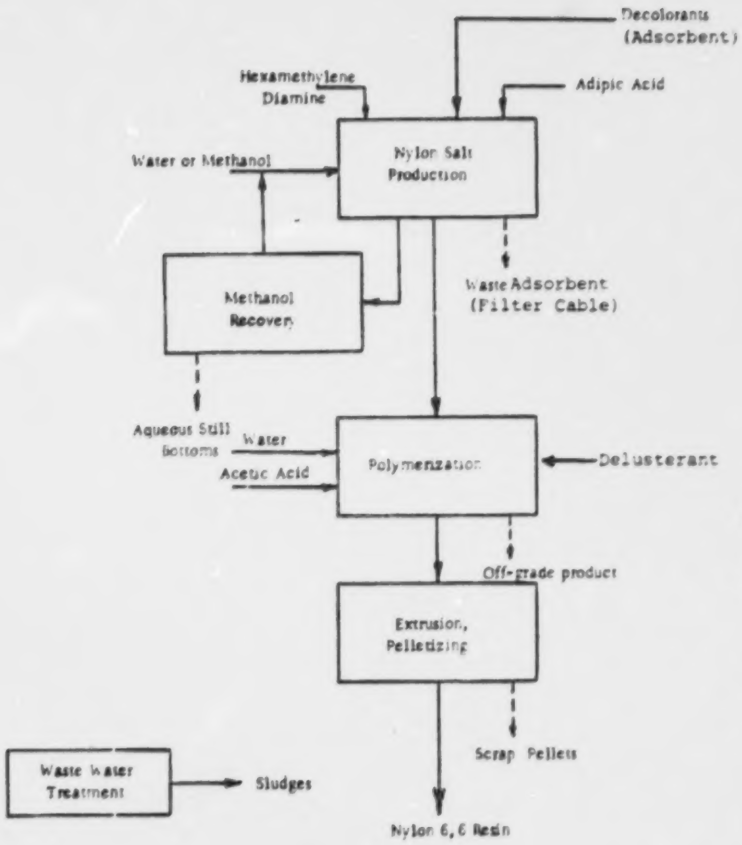

WET PROCESS
Water
Caprolactam
Reactor
Polymer Surge Tank
Spin Pump
Monomer Recovery
K Mn O4
Hot Water
Still Bottoms
Depolymerizer Dehydrator
Extraction Vessel
Cutter
Quench Tank
Waste Water
Waste Water
Polymer Scrap
K Mn O4 Waste
Filter
Dryer
Nylon 6
Fines from dust collectors
Waste Water Treatment
Sludges
DRY PROCESS
Recovered Monomer
Monomer Recovery
Still Bottoms
Vacuum Stripper
Caprolactam
Water
Reactor
Polymer Surge Tank
Spin Pump
Quench Tank
Cutter
Dryer
Nylon 6
Fines from dust collectors
Waste Water
Polymer Scrap
Waste Water Treatment
Sludges

Source: Foster D. Snell, Inc.

Major Solid Wastes	% Total Production
Off-Grade Products	0.02
Still Bottoms and Waste Oils	NA
Total	-

FIGURE II-9

NYLON 6,6 (POLYAMIDE) FLOW DIAGRAM


Decolorants
(Adsorbent)
Hexamethylene Diamine
Adipic Acid
Water or Methanol
Nylon Salt Production
Methanol Recovery
Waste Adsorbent
(Filter Cable)
Aqueous Still Bottoms
Water
Acetic Acid
Polymerization
Delusterant
Off-grade product
Extrusion, Pelletizing
Scrap Pellets
Waste Water Treatment
Sludges
Nylon 6,6 Resin

Wastes	% Total Production
Off-Grade Products	0.30
Still Bottoms and Waste Oils	NA
Others	
Wastewater Sludge and Spent Filter Coke	0.36
Total	-

Source Foster D. Snell, Inc., and EPA study (Contract No. 68-01-0030) cess contain large amounts (1%) of hexamethylene diamine. Though this material is readily biodegradable in the treatment facilities, it contributes to the biological sludge formed.

3.2.2.3 Polyesters

The polyesters used for fiber production are glycol terephthalates which polymerize to polyethylene terephthalate with the formation of recoverable ethylene glycol (Figure II-10). The primary reactant may be the ester, dimethyl terephthalate, in which case methanol is evolved during the esterification reaction preceding the polymerization. It is a frequent practice to return the glycol and methanol streams to the manufacturer. In this case, whatever still bottoms are associated with those streams are handled as part of the glycol or methanol production processes.

The catalysts used in polyester manufacture are reported to include acetates of cobalt, manganese and cadmium. These catalysts may obviously give rise to potentially hazardous waste streams, particularly in primary sludges of water treatment facilities. It was not possible to obtain data on these materials and no sludge production was reported.

Some manufacturers acknowledge the presence in their solid wastes of comparatively large quantities of zinc compounds. But zinc chloride is widely used as a solution agent for certain types of solution spinning and this may constitute a larger source of this ion than the polymerization operations.

3.2.3 Non-Olefinic Polymers Primarily Used As Resins

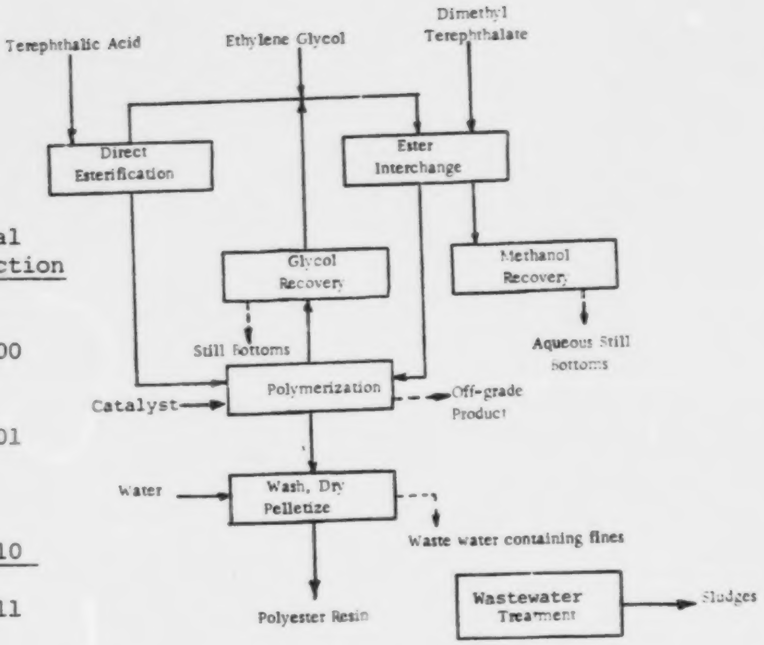
A series of figures are provided to illustrate the processes and waste streams discussed under non-olefinic polymers primarily used as resins.

- Phenolic resins--Figure II-11
- Amino resins--Figure II-12
- Coumarone-Indene resins--Figure II-13

FIGURE II-10

POLYESTER RESIN FLOW DIAGRAM

Wastes	% Total Production
Off-Grade Products	3.00
Still Bottoms and Waste Oils	0.01
Others Terephthalic Acid	0.10
Total	3.11


Terephthalic Acid
Ethylene Glycol
Dimethyl Terephthalate
Direct Esterification
Ester Interchange
Glycol Recovery
Methanol Recovery
Still Bottoms
Aqueous Still Bottoms
Catalyst
Polymerization
Off-grade Product
Water
Wash, Dry Pelletize
Waste water containing fines
Wastewater Treatment
Sludges
Polyester Resin

Source: Foster D. Snell, Inc., analysis and EPA study (Contract No. 68-01-0030)

- Epoxy resins--Figure II-14
- Alkyd resins--Figure II-15
- Polyurethane--Figure II-16
- Silicones--Figure II-17

The products in this group are arranged according to two criteria: production technologies and production volumes. The first three, phenolics, amino and coumarone-indene resins, are produced in specialized, identifiable facilities with relatively large yearly production. Within the group, the phenolic resins have the highest production volume. The last group, consisting of resins, epoxy, alkyds and polyurethanes and silicones are made in thousands of various formulations, in hundreds of locations with considerable differences in the size of plants, in the sophistication of equipment used and in the production technologies. The process descriptions for these resins are only illustrative. Furthermore, the significant variations mentioned above make a generalization of waste stream data infeasible.

3.2.3.1 Phenolic Resins

These resins are formed by reacting phenol, or a substituted phenol, with an aldehyde (Figure II-11). The industry produces two broad types of resins in this category: resols and novolaks.

The waste stream from these two processes consists of partially polymerized material, containing an excess of phenol, which appears as a suspension in the water distillates. As noted later, no satisfactory method of handling this waste stream has yet been devised. Some major manufacturers are reportedly at work on this problem, but consider the development of such a method to be a highly proprietary item.

3.2.3.1.1 Resol Manufacture

Molten phenol (Figure II-11) is fed to the reaction kettle, followed by formaldehyde. This serves to clear the lines of residual phenol. A catalyst solution of sodium hydroxide is then added and the kettle heated to about 60°C.

When the desired degree of polymerization has occurred, the kettle is cooled to about 35°C to inhibit further reaction. The caustic may be neutralized in the kettle with sulfuric acid at this time. The water from this distillation forms a concentrated waste of unreacted materials and low molecular weight resin.

The batch is dumped and, depending on the specific resin, the batch may be washed several times and a vacuum may be used during the dehydration cycle. It is important that molten resin be handled quickly to avoid its settling up to an insoluble, infusible mass, which would become a waste.

3.2.3.1.2 Novolak Manufacture

Novolak manufacture is almost identical to that of resol (Figure II-11). The major difference is that sulfuric acid is used as a catalyst. Because of this, vacuum reflex must be used to maintain a temperature of 85-90°C, which is slightly higher than for resols. The reaction continues for 3 to 6 hours at which time the condensate is switched to the receiver and water is removed by vacuum. The temperature goes to about 120-160°C. This reaction does not have to be cooled because polymerization is complete.

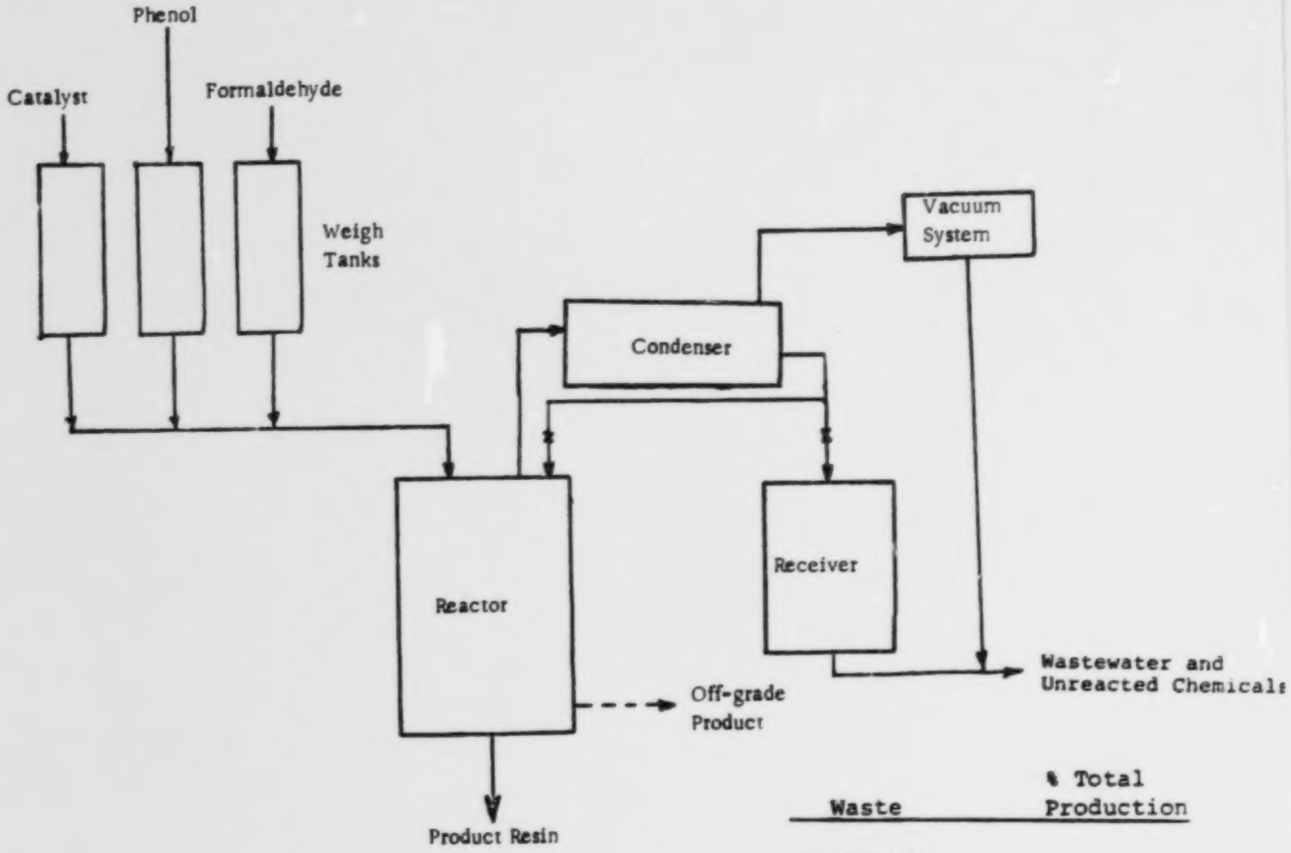
The product is allowed to solidify or solvents may be added to keep it in a molten form. If solidified, it is ground to powder or flake form before being shipped.

3.2.3.2 Amino Resins Manufacture

When formaldehyde is reacted with certain nitrogen containing organic chemicals, in particular urea and melamine, an amino resin is formed (Figure II-12). Typically, amino resins are manufactured in a standard batch polymerization process. Because many specialty grades are made, the batches are frequently small.

FIGURE II-11

PHENOLIC RESIN FLOW DIAGRAM


Phenol
Catalyst
Formaldehyde
Weigh Tanks
Vacuum System
Condenser
Reactor
Receiver
Wastewater and Unreacted Chemicals
Off-grade Product
Product Resin

Waste	% Total Production
Off-Grade Products	0.8
Still Bottoms and Waste Oils	3.8$^{(1)}$
Others	
Wastewater Sludge	6.0
Total	10.6

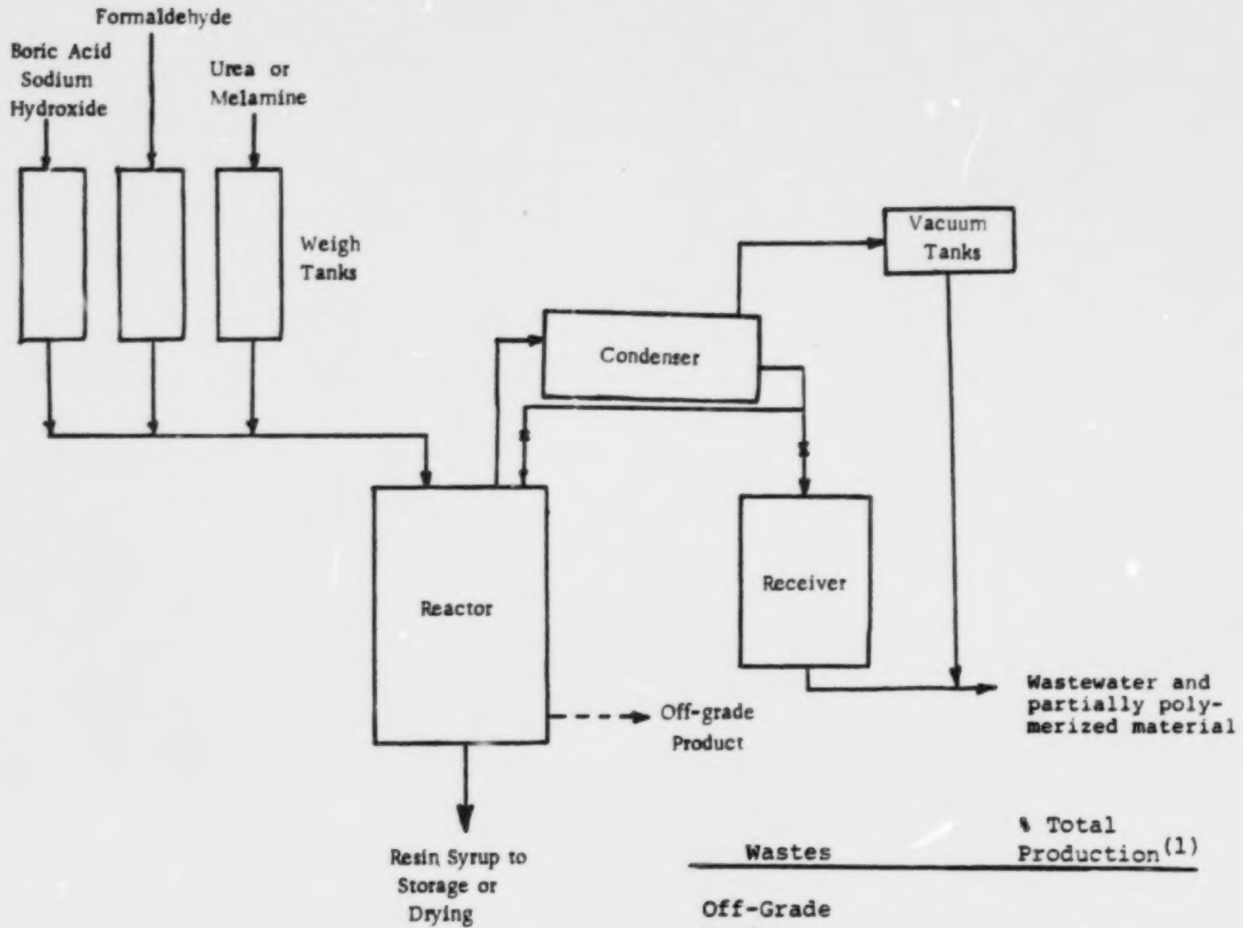
---

(1) Dry Basis

Source: EPA publication EPA-440/1-74-010-a

FIGURE II-12

AMINO FORMALDEHYDE RESIN FLOW DIAGRAM


Formaldehyde
Boric Acid
Sodium
Hydroxide
Urea or
Melamine
Weigh
Tanks
Vacuum
Tanks
Condenser
Reactor
Receiver
Wastewater and
partially poly-
merized material
Off-grade
Product
Resin Syrup to
Storage or
Drying

Source: EPA publication EPA-440/1-74-010-a

Wastes	% Total Production(1)
Off-Grade Products	1.0
Still Bottoms and Waste Oils	1.2
Others Filter Coke	0.24
Total	5.44

---

(1) Illustrative Data Only

Formaldehyde is put in the kettle and the pH adjusted to about 7.0-7.8. The catalyst, boric acid, is added and then the urea or melamine. The pH is adjusted again to near neutral. The reaction proceeds at 100°C under atmospheric reflux conditions for about 2 hours. Then, a vacuum is applied and the temperature dropped to 40°C for about 5 hours. The system is then put on total reflux and the pH adjusted to slightly alkaline. The material may either be shipped as a liquid or dried and powdered.

In some instances, formaldehyde is received in a pure state. In this case, there is a tendency for solid formaldehyde polymers to be produced--para-formaldehydes. These are highly flammable solids, giving off strong formaldehyde fumes. Bad batches, containing large excesses of unreacted formaldehyde, require disposal.

3.2.3.3 Coumarone-Indene Resins

The name of this group of resins is somewhat misleading. Initially, these resins were condensation products of a coal tar fraction consisting essentially of coumarone and indene. At present, the bulk of the production is based on the condensation of various reactive chemical species present in heavy petroleum distillates (boiling point in the range of 100°C to 250°C).

In summary, there are two groups of raw materials:

- C-I crudes (coumarone-indene fraction of coal tar distillates)
- Petroleum distillates.

Lighter fractions of petroleum distillates are used in the process as a diluent.

Coumarone-indene resins are manufactured by two basic methods:

- Thermal polymerization
- Solvent polymerization.

In thermal polymerization (Figure II-13), the raw materials are blended to a predetermined composition, then heated under pressure. After the polymerization has reached the desired point, the reaction is vented to a condenser where a distillate (sometimes called "inert") is recovered. The batch is then steam stripped under vacuum until the desired hardness is achieved. The resin is then transferred to packaging kettles.

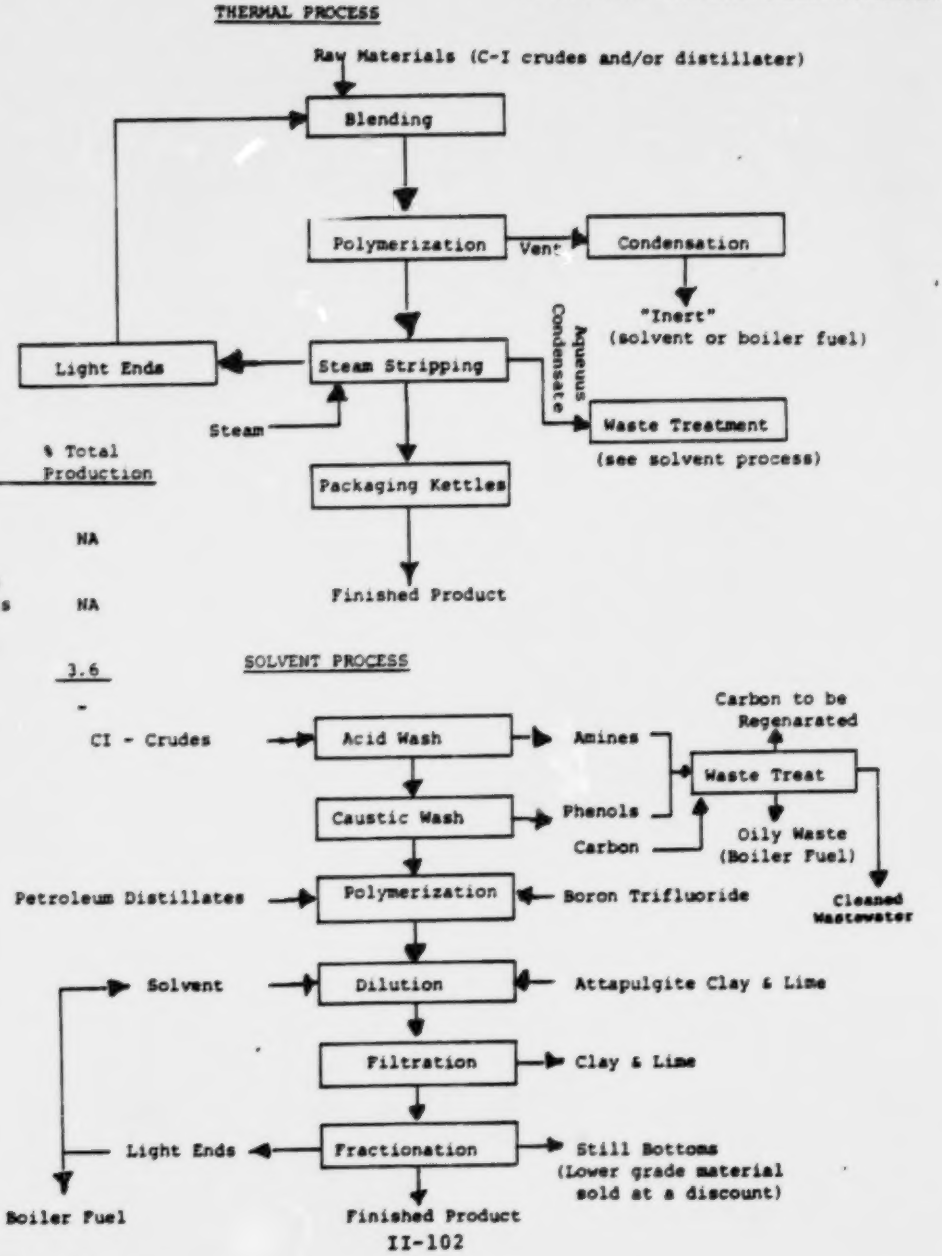
The solvent process (Figure II-13) may take two forms depending on raw materials. If the C-I crudes are used as the starting material, acid and caustic washes are required to remove amines and phenols which are present in the crudes. This procedure is not required if petroleum distillates are the raw material. This is the only difference between the two forms.

A polymerization catalyst is used. It is usually boron trifluoride. The mixture is then heated until the desired degree of polymerization is achieved. At this point, additional diluent and a mixture of attapulgite clay and lime are added to the reactor. The mass is then filtered in a continuous vacuum filter to remove the clay and lime.

The filtrate undergoes fractional distillation. The low boiling fractions are recycled as diluent or burned as boiler fuel. The middle fractions constitute the desired product and the still bottoms are sold as a lower grade product.

The waste streams from these operations are the clay/lime cake, which may contain some fluorine and some boron, and the products from wastewater treatment. In most installations, the wastewater treatment includes a trap which collects the waste oils. These are used as fuel for the boilers. The final wastewater treatment consists of carbon adsorption. The spent carbon is returned to the supplier for regeneration. The amount of carbon and oily wastes varies according to the product mix. The waste clay/lime residue is a function of the amount of resin produced by the solvent process.

FIGURE II-13
COUMARONE-INDENE FLOW DIAGRAM


THERMAL PROCESS
Raw Materials (C-I crudes and/or distillater)
Blending
Polymerization
Vent
Condensation
"Inert" (solvent or boiler fuel)
Light Ends
Steam Stripping
Aqueous Condensate
Steam
Waste Treatment
(see solvent process)
Packaging Kettles
Finished Product
SOLVENT PROCESS
CI - Crudes
Acid Wash
Amines
Carbon to be Regenarated
Waste Treat
Caustic Wash
Phenols
Carbon
Oily Waste (Boiler Fuel)
Cleaned Wastewater
Petroleum Distillates
Polymerization
Boron Trifluoride
Solvent
Dilution
Attapulgite Clay & Lime
Filtration
Clay & Lime
Light Ends
Fractionation
Still Bottoms (Lower grade material sold at a discount)
Boiler Fuel
Finished Product
II-102

Wastes	% Total Production
Off-Grade Products	NA
Still Bottoms and Waste Oils	NA
Others (spent clay)	3.6
Total	-

Source: Foster D. Snell, Inc.

3.2.3.4 Epoxy Resins

The bulk of the epoxy resins are produced by the condensation of epichlorohydrin with bisphenol A (4.4'-isopropylidenediphenol). However, formulation variants involve the use of other polyols, i.e., aliphatic glycols. Sometimes epichlorohydrin is reacted with Novolak type phenolic resins, thus transforming them into epoxy type products.

The final desired properties are obtained by achieving a combination of basic resin formulation of the degree of polymerization desired and of curing agents. These are added at the point of use, so that the final products are made by mixing a resin component with a curing component, very often in equal or nearly equal volumes. The curing agents cover a broad range of chemical species: amines, polyamides, acids and anhydrides, or even resins of the phenolic or the polyamino groups.

The bulk of the commercial production is in the so-called lower molecular weight group (M.W. 360-650) which is liquid at room temperature. Higher molecular weight material has a consistency varying from "taffy" (M.W. 800-1,000) to brittle solid (M.W. 2,000-8,000). The highest molecular weight material (M.W. 5,000-8,000) melts at 145-155°C.

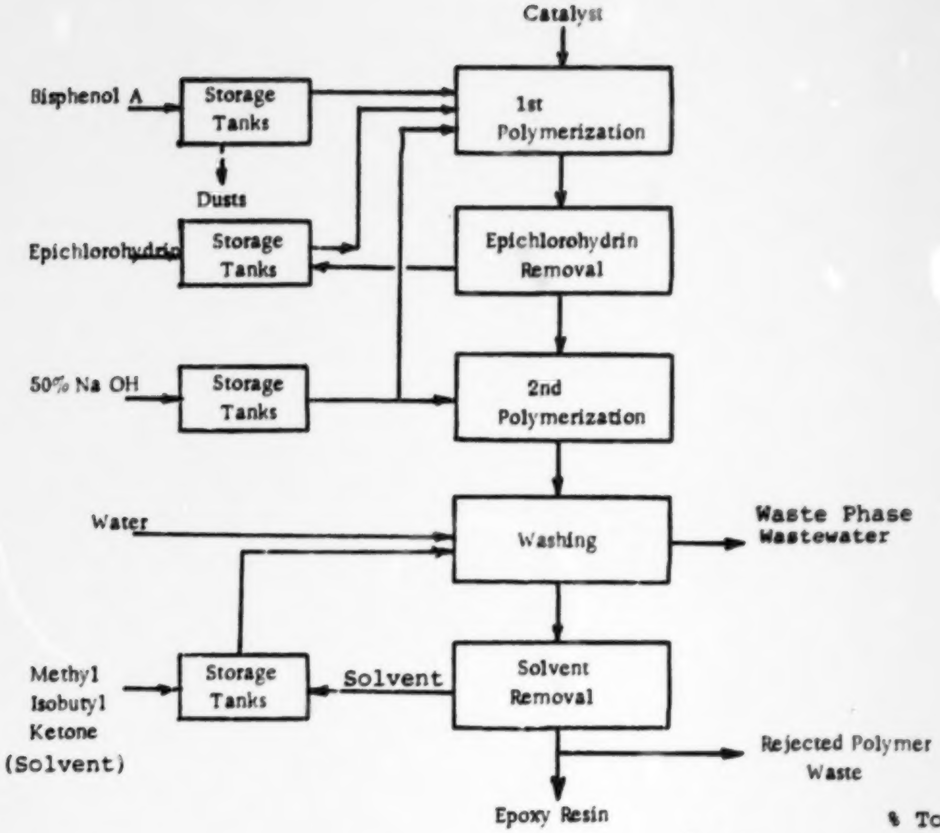
The production processes vary enormously in technology and capacity. The processes described in the following paragraphs are only illustrations. The formulations of the catalysts, which are used to promote the desired straight line reaction over an undesirable branching type of reaction, are highly proprietary.

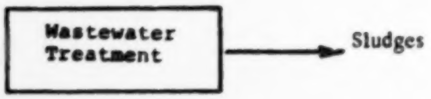
3.2.3.4.1 Continuous Process

The process described here (Figure II-14) is a two-step process. Bisphenol A, epichlorohydrin, catalyst and 50% caustic soda solution are continuously fed at appropriate rates to a first polymerization chamber. The material then passes continuously to epichlorohydrin removal where

FIGURE II-14

EPOXY RESIN FLOW DIAGRAM
(CONTINUOUS PROCESS)


Catalyst
Bisphenol A
Storage Tanks
Dusts
1st Polymerization
Epichlorohydrin
Storage Tanks
Epichlorohydrin Removal
50% Na OH
Storage Tanks
2nd Polymerization
Water
Washing
Waste Phase Wastewater
Methyl Isobutyl Ketone (Solvent)
Storage Tanks
Solvent
Solvent Removal
Rejected Polymer Waste
Epoxy Resin


Wastewater Treatment
Sludges

Waste	% Total Production
Off-Grade Products	NA
Still Bottoms and Waste Oils	NA
Others	NA
Total	-

Source: EPA publication EPA-440/1-74-010-a

excess epichlorohydrin is removed and returned to the storage area. The material stripped from epichlorohydrin goes to a second polymerization chamber, where an additional amount of 50% caustic is introduced at the appropriate rate. The material leaves the chamber to go to a washing operation where water and methyl isobutyl ketone are added to provide a two-phase system which is continuously separated, the water phase being discarded. A final step consists of solvent removal. The solvent is then recycled to the washing operation. The waste streams in this process are unusable off grade product and wastewater which usually has to be treated by a conventional treatment system.

3.2.3.4.2 Batch Process

In this variant of the process, the operations of first and second polymerization, epichlorhydrin removal, washing and solvent removal are carried out successively in the same vessel. However, in this case, at the end of the operations the temperature is such that the resin is in the molten state at between 70°C and 150°C. This process is sometimes referred to as the batch fusion process. The molten resin is allowed to solidify and then can be flaked or ground to a powder. The waste streams are the same as in the continuous process. Proprietary catalysts are believed to be discarded in solution in the wastewaters.

3.2.3.5 Alkyd Resins

Chemically, the alkyl resins are the products of the reaction (esterefication) of various polyhydric alcohols (polyols) with holy basic acids (e.g.), phtalic or malic acid) and unsaturated aliphatic acid (fatty acids).

Alkyds are made generally in liquid form and are further compounded and modified at their point of use. There are innumerable formulas and ingredient combinations.

Individual production units are usually quite small and often associated with larger manufacturing facilities, principally in the paint and coatings industry SIC 285.

The problem with this particular group of polymers is that the esterification reaction between acid and hydroxyl (alchol) groups (-CHOH and -COOH) releases a mole of water. Since the reaction is reversible, this water has to be removed to allow the reaction to continue to proceed in the desired esterification direction. Two main processes (Figure II-15) are used to achieve this end:

- In the solvent process, the reactants are introduced into a polymerization kettle. A solvent, such as xylene, is continuously added to the kettle and allowed to distill out as an azeotrope carrying the water vapor. In a solvent recovery unit, the water is separated as an aqueous stream and the solvent returned to the kettle.

  After completion of the polymerization, the resin is thinned with a solvent (xylene) in a thinning tank and the mixture is filtered to remove solid waste (off grade product).

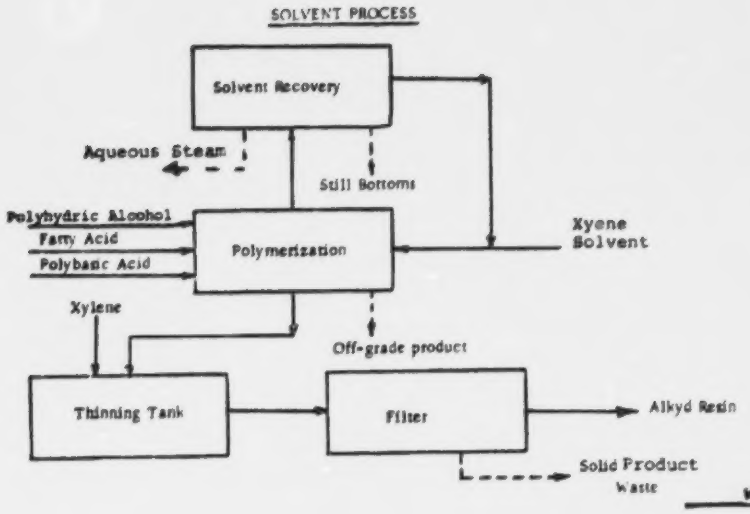
- In the dry process, also known as fusion process, the materials are introduced into a polymerization kettle, a stream of inert gas is sparged through the mixture to carry out the water vapor formed. When polymerization is complete, the resin is transferred to a thinning tank, solvent is added and the mixture is filtered.

3.2.3.6 Polyurethanes

Polyurethanes are obtained by reacting di-isocyanates or polyisocyanates with polyols or polyamines (Figure II-16). Many of these reactions can be carried out at the point of use in completely unsophisticated equipment amounting to little more than a kettle with a stirrer. Formulations encompass literally thousands of varying combinations of ingredients, mostly proprietary.

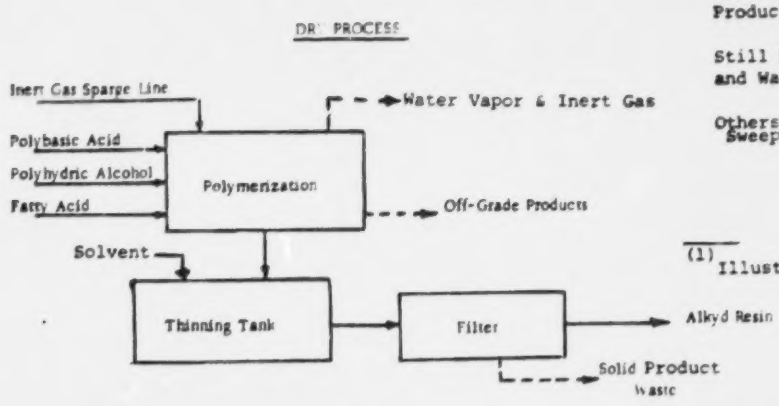
FIGURE II-15

ALKYD RESIN FLOW DIAGRAM


SOLVENT PROCESS
Solvent Recovery
Aqueous Steam
Still Bottoms
Polyhydric Alcohol
Fatty Acid
Polybasic Acid
Polymerization
Xyene Solvent
Xylene
Off-grade product
Thinning Tank
Filter
Alkyd Resin
Solid Product Waste

Wastes	% Total Production(1)
Off-Grade Products	0.10
Still Bottoms and Waste Oils	NA
Others Sweepings	0.01
Total	-

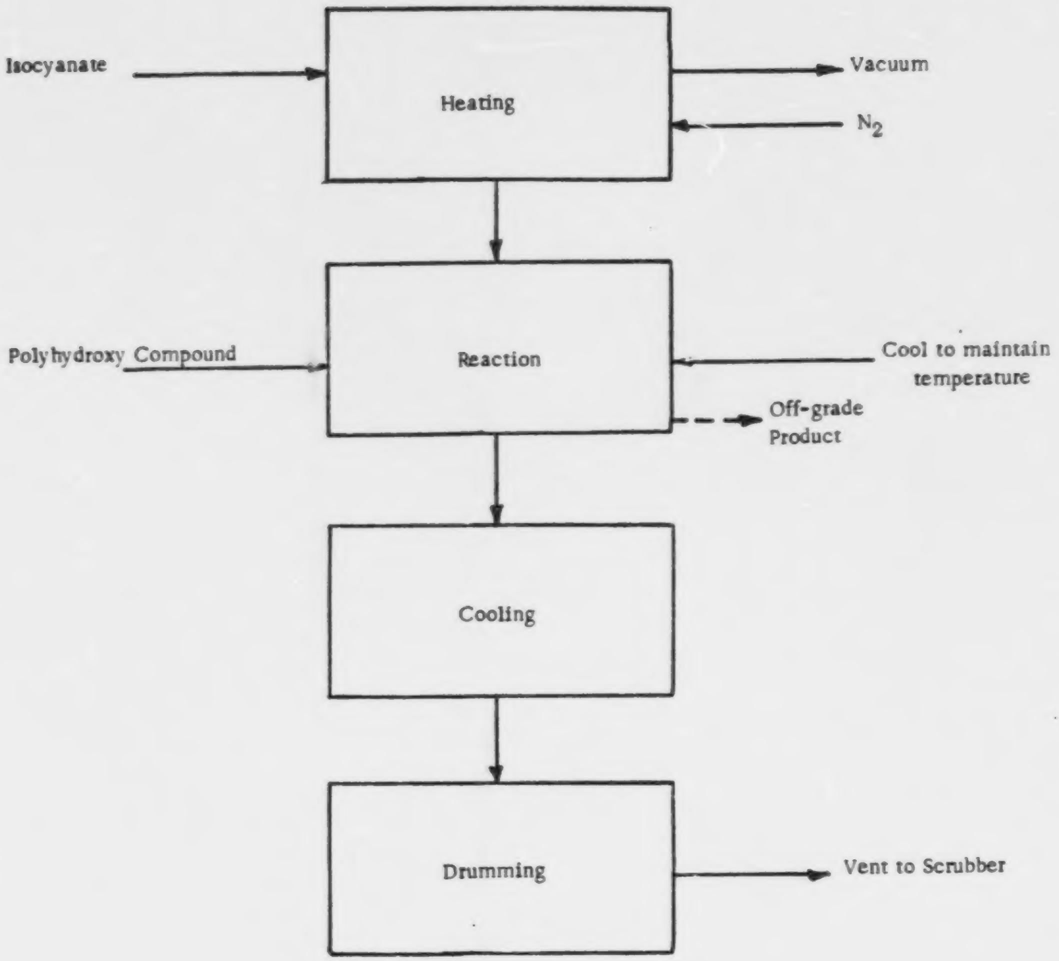
(1) Illustrative data only


DRY PROCESS
Inert Gas Sparge Line
Water Vapor & Inert Gas
Polybasic Acid
Polyhydric Alcohol
Fatty Acid
Polymerization
Off-Grade Products
Solvent
Thinning Tank
Filter
Alkyd Resin
Solid Product Waste

Source Foster D. Snell, Inc.

FIGURE II-16

POLYURETHANE FLOW DIAGRAM


Isocyanate
Heating
Vacuum
N_2
Polyhydroxy Compound
Reaction
Cool to maintain temperature
Off-grade Product
Cooling
Drumming
Vent to Scrubber

Source Foster D. Snell, Inc.

The only production of polyurethanes by SIC 2821 appears to be that of "prepolymers." These prepolymers are complex mixtures of partially polymerized products and usually of highly proprietary formulation.

The prepolymers are classified as reactive and non-reactive. These names refer to the subsequent steps necessary to complete polymerization. Reactive prepolymers can polymerize by action of atmospheric moisture. The mechanism of polymerization of the non-reactive prepolymers can be straight air oxidation or may require the addition of a reactant mixture.

Most of the production is carried out directly from the monomers (often referred to as compound A and compound B) by plants outside the SIC 2821. For instance, production is carried out by automotive accessory manufacturers (cushions, padding), by paint plants or by appliance manufacturers (i.e., refrigerators). In addition, the global production figure is only about 50,000 KKg per year (100 million lbs./year).

3.2.3.7 Silicones

Silicone rubber and resins are made by the polymerization of several silicone monomers or oligimers. The backbone of the polymer is based on Si atom(s) rather than on C atom(s). The silicones are usually manufactured in extremely complex plants, which often incorporate in their operation the production of the monomers themselves. In addition, the products of polymerization are arbitrarily classified between segments 2821 and 2822 of the SIC 282 group and segment 2869 of the SIC 286 Industrial Organic Chemical Industries.

Silicones are produced in only a few plants in the United States. The production methods, processes and even products and by-products are highly proprietary.

The process descriptions and flow diagrams presented in this study represent information developed by direct discussion and interviews with industry representatives and are limited by considerations of possible inadvertent disclosure of confidential information.

In very general terms, there are two initial parallel operations resulting in products classified in SIC 2821 and 2822:

- A bulk polymerization step producing gums and hydrolyzed silanes

- An emulsion or suspension polymerization process producing silanol fluids.

In addition, there are further processing operations:

- The gums produced by bulk polymerization are compounded as silicone rubber plastics.

- The gums are disposed in solvent and marketed as dispersion (plastisols).

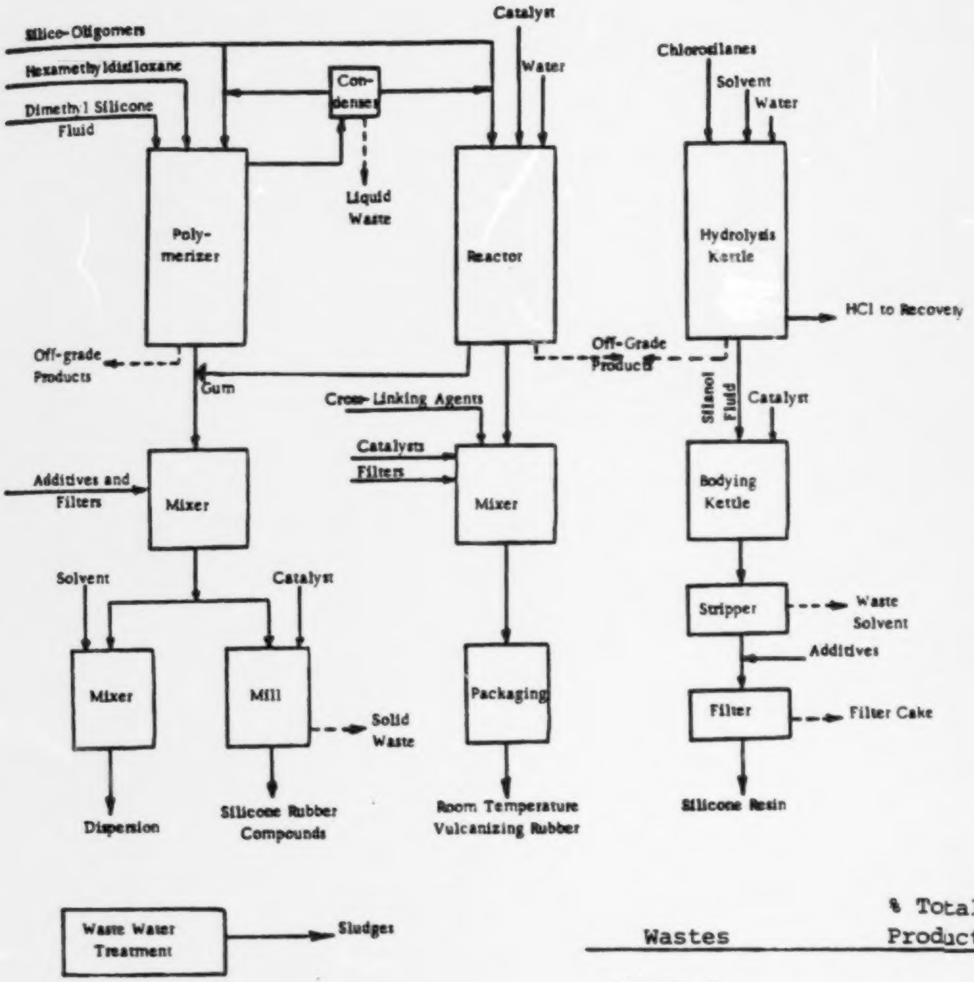
- Further processing of by-product streams of bulk polymerization leads to the production of room-temperature vulcanizing rubber (RTVR).

An alternative route leading to silicone resins starts with chlorosilane compounds. These compounds are hydrolyzed in a reactor containing water and an immiscible solvent. The water layer containing hydrochloric acid is discarded and the solvent layer containing the hydrolyzed silanes is polymerized to silicone resins by addition of catalyst and heating. Figure II-17 summarizes the process involved.

The following descriptions are illustrative and are intended to key some reported waste streams, the exact origin of which is proprietary.

FIGURE II-17

SILICONE PRODUCTS FLOW DIAGRAM


Silico-Oligomers
Hexamethyldisiloxane
Dimethyl Silicone Fluid
Condenser
Liquid Waste
Catalyst
Water
Chlorosilanes
Solvent
Water
Polymerizer
Reactor
Hydrolysis Kettle
HCl to Recovery
Off-grade Products
Gum
Off-Grade Products
Silanol Fluid
Catalyst
Cross-Linking Agents
Catalysts
Filters
Additives and Filters
Mixer
Mixer
Bodying Kettle
Solvent
Catalyst
Stripper
Waste Solvent
Additives
Mixer
Mill
Solid Waste
Packaging
Filter
Filter Cake
Dispersion
Silicone Rubber Compounds
Room Temperature Vulcanizing Rubber
Silicone Resin
Waste Water Treatment
Sludges

Wastes	% Total Production
Off-Grade Products	5.4
Still Bottoms and Waste Oils	5.8
Spent Adsorbent and Scrap	3.3
Total	14.5

Source: Foster D. Snell, Inc.

3.2.3.7.1 Gum Production

Silicone gum is produced by polymerization of a mixture of silico-oligomers in the presence of a catalyst. Volatile compounds are evolved during the operation and are partly returned to the process after condensation and partly disposed of as liquid wastes. Prior to being fed to the reactor, some of the oligomers are dried by adsorption on silica gel type molecular sieves. These are discarded from time to time giving rise to a waste stream. Cleanings of the equipment and off-grade unusable products are also disposed of. The product gums are used as raw materials for the production of silicone rubber.

3.2.3.7.2 Silicone Rubber Compounding

One type of silicone rubber is produced by compounding gums, additives and fillers on a Banbury mixer. The product is further compounded (refined) on roll mills. These operations produce a liquid waste stream and a solid waste stream.

3.2.3.7.3 Silicone Resin Production

The starting materials for this production are a mixture of chlorosilanes and solvent. The first step involves the hydrolysis of the chlorosilane by addition of water. This is followed by gravity or centrifuge separation of the water layer. The next step is the polymerization step, sometimes called bodying. This step is carried out in an agitated kettle with addition of a catalyst (sometimes a salt of zinc) and by heating. The solvent is then stripped off and usually disposed of as waste. At this point, some resins are simply cooled and flaked. Other resins are obtained by addition of various proprietary ingredients. When the additives have dissolved, the resin is filtered over filter presses and allowed to cool. The waste streams in this process are, in addition to the waste solvent already mentioned, the filter cake and some scrap resin--either off-grade product or from cleaning the reactors.

3.2.4 Cellulosic Products

Chemically, there are two fundamental groups of cellulosic products: the rayons and the acetates. At present, the bulk of the production of these materials is for fiber manufacture. However, there is still a significant production for films (cellophane and photographic films of acetate). The rayons are basically reconstituted cellulose. The acetates are reaction products of cellulose with acetic anhydride. The most recent form is known as the triacetate. In the U.S. the term "rayon" includes man-made textile fibers and filaments composed of regenerated cellulose. The term "acetate" has been adopted to indicate man-made textile fibers and filaments composed of cellulose acetate.

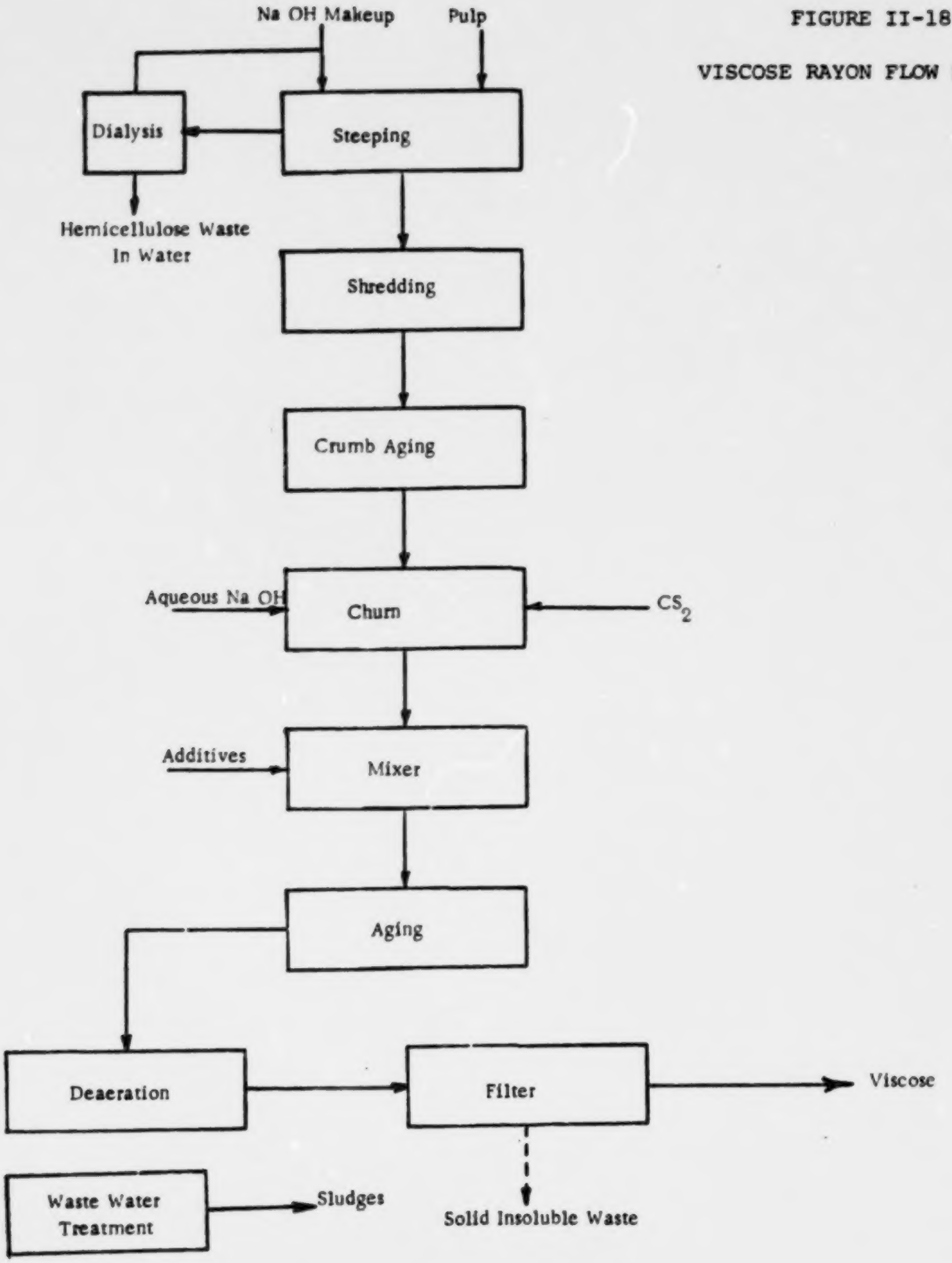
3.2.4.1 Rayon

Chemically, rayon is a modified cellulose, which is the main constituent of wood pulp. Since 1910 to 1911, the rayon in the United States has been produced by the Viscose process (Figure II-18). Wood pulp (pulp) is slurried in a caustic solution (NaOH), then the excess caustic is expressed and goes to a dialysis step to separate the hemicellulose formed by reaction of caustic with some of the cellulose. The treated caustic solution is returned from the dialysis to the steeping operation. The treated pulp from the steeping process goes to a shredding operation which forms crumbs. The crumbs are aged in the crumb aging operation under controlled conditions. The crumbs are reacted in a churn with aqueous NaOH (dilute caustic) and carbon disulfide (CS_2) to form cellulose xanthate. Proprietary additives are added in a mixer and a second aging process takes place. Then, the slurry goes to a deaeration step, followed by a filtering step, and a viscose solution is obtained that can be used for a casting operation to form cellophane on a spinning operation to form fibers.

The waste streams from this operation consists of solutions of hemicellulose and a solid waste, which is in effect an off-grade product. Difficulties in meeting water effluent guidelines have resulted, and continue to result, in the decline of rayon production in the United States. Numerous large production facilities have been closed down.

FIGURE II-18

VISCOSE RAYON FLOW DIAGRAM


Na OH Makeup
Pulp
Dialysis
Steeping
Hemicellulose Waste In Water
Shredding
Crumb Aging
Aqueous Na OH
Churn
CS_2
Additives
Mixer
Aging
Deaeration
Filter
Viscose
Waste Water Treatment
Sludges
Solid Insoluble Waste

Source: EPA publication EPA-440/1-74-010-a

3.2.4.2 Acetates

There are two basic types of acetates produced in significant quantities. These materials differ only in the degree of acetylation. When 92% or more of the hydroxyl groups in cellulose are acetylated, the product is referred to as cellulose acetate. There are no significant differences in the manufacturing processes of these materials. A flow diagram of the process is presented in Figure II-19.

After shredding, the wood pulp goes to the acetylation process where it is treated first with acetic acid to activate the cellulose. This is then fed to acetylation reactors where it is treated with acetic anhydride. A clear viscous solution of cellulose acetate in water is obtained.

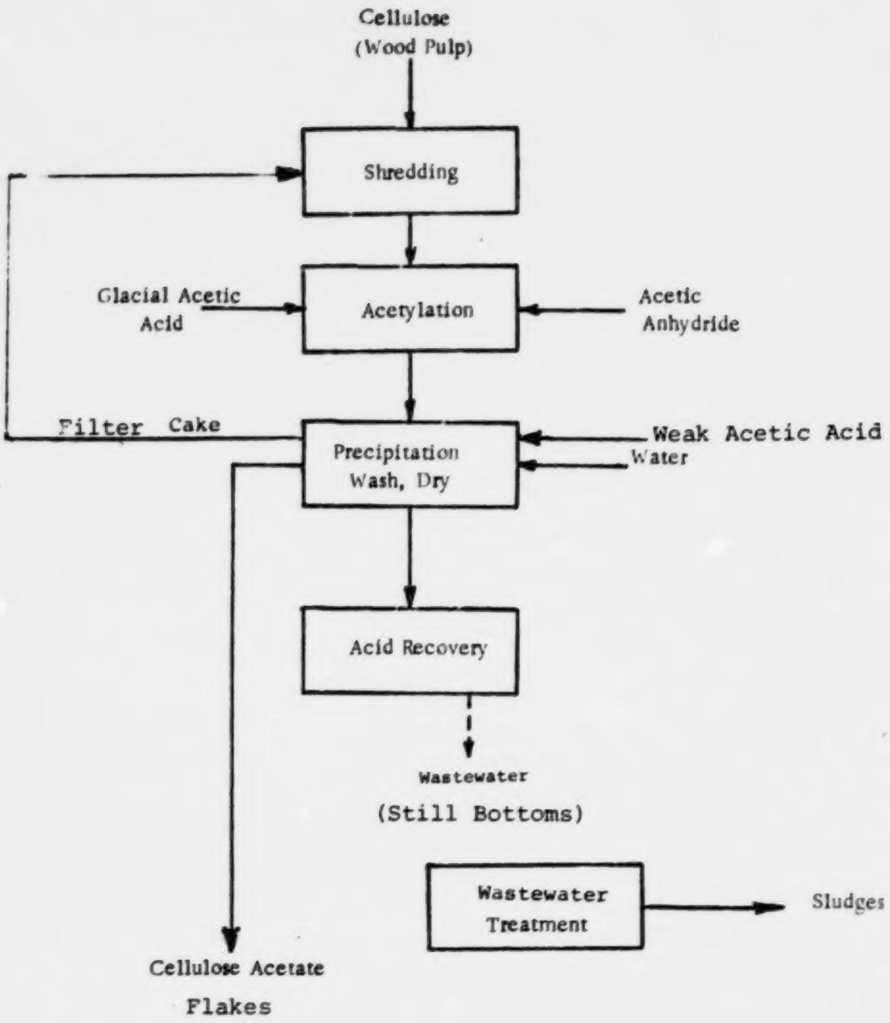
The product is recovered as a flake by precipitation with a weak acetic acid solution and countercurrent water wash. The flakes are dewatered on a vibrating screen and dried in an oven. The water stream from the vibrating screen is filtered and the filter cake is returned to the head of the process; therefore, a waste is not created. The filtrate is sent to acetic acid recovery. The acid recovery is performed by extractive distillation with a proprietary solvent. The still bottoms include a concentrated solution of magnesium sulfate, soluble cellulose products and a trace of the solvent.

3.2.5 Spinning Processes

Spinning operations are significantly different from the polymerization processes described in the previous sections. Spinning differs from polymerization both in terms of the equipment used and the type of physico-chemical changes occuring. In many instances, a form of further polymerization takes place; however, this polymerization is in the form of cross-linking. Cross-linking is similar in chemical terms to the vulcanization of rubber which is discussed in Volume III of this report.

FIGURE II-19

CELLULOSE ACETATE RESIN FLOW DIAGRAM



Cellulose
(Wood Pulp)
Shredding
Glacial Acetic
Acid
Acetylation
Acetic
Anhydride
Filter Cake
Precipitation
Wash, Dry
Weak Acetic Acid
Water
Acid Recovery
Wastewater
(Still Bottoms)
Wastewater
Treatment
Sludges
Cellulose Acetate
Flakes

Source EPA study (Contract No. 68-01-0030)

Fundamentally, spinning is an extrusion process (Figure II-20) in which the polymer is forced through spinnerets either in solution form or as a melt. The spinning operation may also be an extension of the basic polymerization process. When the polymer is in solution form, it is called a dope. The solvent can be water, an aqueous salt solution or a water miscible organic liquid.

There are three basic spinning methods:

- Melt spinning where the extruded fiber solidifies by cooling
- Wet spinning in which the fiber solidifies by coagulation in a bath
- Dry spinning where the fiber solidifies by evaporation of the solvent.

Subsequent treatment may involve stretching, washing, bleaching, lubricating, crimping and dyeing. The order of these steps varies according to the products treated and the result desired.

Spun fibers include monofilament (a single, untwisted synthetic filament) and yarns, staples and tow. Staple and tow are produced by chopping the fibers to desired lengths. Staple in general has shorter fiber lengths than tow and is used in further spinning operations characteristic of typical textile operations. Tow is used in such applications as filters for cigarettes. Monofilaments and yarns are directly processed into fabrics, ropes, etc.

A synoptic presentation of spinning processes is provided in Table II-38 for the most common fibers. Processing steps and wastes generated are discussed in greater detail in the following paragraphs for each of these fibers. The discussion is organized in the order of production volume.

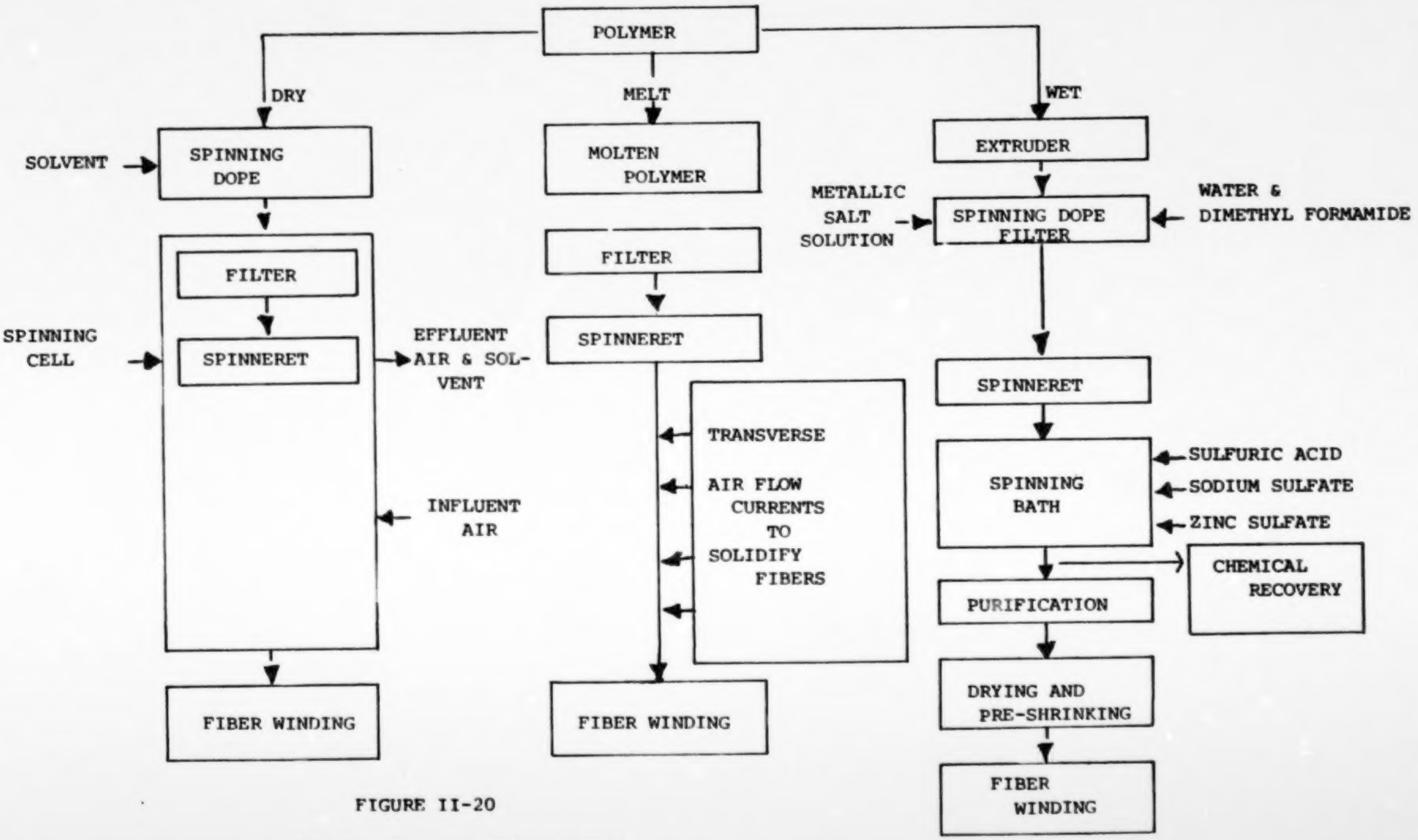

POLYMER
DRY
MELT
WET
SOLVENT
SPINNING DOPE
FILTER
SPINNING CELL
SPINNERET
EFFLUENT AIR & SOLVENT
INFLUENT AIR
FIBER WINDING
MOLTEN POLYMER
FILTER
SPINNERET
TRANSVERSE AIR FLOW CURRENTS TO SOLIDIFY FIBERS
FIBER WINDING
EXTRUDER
METALLIC SALT SOLUTION
SPINNING DOPE FILTER
WATER & DIMETHYL FORMAMIDE
SPINNERET
SPINNING BATH
SULFURIC ACID
SODIUM SULFATE
ZINC SULFATE
CHEMICAL RECOVERY
PURIFICATION
DRYING AND PRE-SHRINKING
FIBER WINDING

FIGURE II-20

SPINNING PROCESS FLOW DIAGRAM.

TABLE II-38

SYNOPTIC DESCRIPTION OF SPINNING PROCESSES

Fiber	Method	Solvent	Bath	Secondary Bath	Further Treatment	Bath Reclaim
Rayon	Wet spinning	Water	Water solution of sulfuric acid, sodium and zinc sulfate	Dilute acid	Stretching - water washes, drying	Evaporation, crystallization, composition correction
Polyester	Melt spinning	None	Cool air	Finish application	Stretching, crimping	
Cellulose Acetate	Dry spinning	Acetone	Hot air to evaporate solvent		Fiber lubrication	Carbon adsorption, steam stripping, distillation
Cellulose Triacetate	Dry spinning	Methanol and methylene chloride	Hot air to evaporate solvent		Fiber lubrication	Carbon adsorption, steam stripping, distillation
Acrylic Fiber	Wet spinning	Water miscible solvent	Water	Water wash	Steam stretching spin finish, crimping, setting	Distillation to recover solvent
	Dry spinning	Solvent	Hot air to evaporate solvent			Carbon adsorption, steam stripping, distillation
Nylon	Melt spinning	None	Cool air	Finish application	Steam or hot water stretching	
Modacrylic (Dynel)	Wet spinning		Water	Water	Finish application, 5 to 15 times stretching, annealing, crimping	Distillation

Source: Foster D. Snell analysis of literature data.

3.2.5.1 Polyester And Nylon Spinning

The same process (melt spinning) is used for the spinning of polyester and of nylon fibers. The polymers (polyester and nylon) are produced by the processes discribed in the previous subsections dealing with polyester and polyomide production.

The polymer is heated to its melt point and filtered through sand or metallic filters. The filters are directly ahead of the spinnerets through which the filtered melt is extruded. The extruded melt is cooled under controlled conditions, and solidified fibers form subsequently.

Polyesters are dry stretched while nylon is stretched in steam or hot water baths. Sometimes, the fibers are crimped and vegetable oil finishes may be applied.

The wastes generated by this process are mostly represented by off-grade material. In many cases, this waste may be depolymerized or returned to the polymerization processes. For example, terephthalic acid can be removed from off-grade polyester fiber and returned to production. Filtering sand is also a waste.

Metallic filters in most cases do not represent a significant waste because they may be regenerated via highly proprietary techniques.

3.2.5.2 Acrylics

There are two methods which can be used for the spinning of acrylic fibers: wet spinning and dry spinning.

- Wet spinning involves two variants:
    - In one, the resin is dissolved in concentrated solutions of mineral salts. Here, the coagulation process consists of leaching out the metal salt(s) from the spun fiber by means of water baths. The salts are usually recovered.

- In the other variant, a water miscible solvent, for example dimethylformamide, is used to prepare the spinning dope. The solvent is leached out by water baths.

- The dry spinning process involves the use of an organic solvent. A recovery step is required. Recovery steps usually involve adsorption of the solvent on activated carbon followed by steam stripping of the saturated carbon and final recovery by distillation or decantation.

From time to time, the carbon beds are replaced. If a significant stream is thus generated, the carbon is returned to the manufacturer for reprocessing. In the case of spinning from a metal salt solution, the metal ions eventually end up in the wastewater treatment sludges. One of the principal salts thus used is reported to be zinc chloride and, therefore, the wastewater treatment sludges contain significant amounts of zinc.

Subsequent steps may involve steam stretching, dyeing, finishing, crimping and settling. No significant wastes are generated.

3.2.5.3 Modacrylics Spinning

Modacrylics differ from acrylics chemically because they are copolymers.

The process used to spin the modacrylic fibers are similar to those used for acrylics and may indeed use the same equipment at certain locations. As an example, the spinning of Dynel is discussed here.(1)

Dynel is a copolymer of acrylonitrile and vinyl chloride prepared by the emulsion process described in paragraph 3.2.2.1. The resin is dissolved in acetone and extruded through a spinneret into an aqueous coagulating bath. After washing to remove the solvent and after the application of a finish, it is stretched from five to fifteen times its original length. Next, the fiber is annealed or baked by exposing the yarn to hot circulating air. This treatment relieves strain and reduces subsequent shrinkage. Finally, the fiber is crimped, cut and baled.

---

(1) Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Volume 17, pp. 168-209, Intersciences Publisher, New York (1967).

Off-grade material constitutes the only significant waste streams generated in spinning of modacrylics.

3.2.5.4 Rayon Spinning

The rayon is manufactured by the process described in section 3.2.4.1, in the form of a solution of cellulose xanthate. This solution, after filtration and deaeration, is pumped through spinnerets into a coagulation bath consisting of a solution of sodium sulfate and magnesium sulfate acidified with sulfuric acid. There are, however, numerous variants in the composition of the xanthate solution and of the bath, which are used to improve the characteristics of the finished product.

The solidification of the rayon fiber in the coagulation bath is a two-step process. As the cellulose xanthate coagulates, there is an accompanying chemical transformation from the xanthate salt to pure cellulose. This is called regeneration and it precedes coagulation.

The net effect of the addition of chemicals to the xanthate solution and/or to the bath is to increase the time lag between these two steps, resulting in an improved tenacity of the fiber. Among the additives reported in the literature are substituted ethylene diamines and dithiocarbamates. Metallic salts, such as zinc chloride, are also used as additives.(1)

---

(1) Kirk-Othmer, Encyclopedia of Chemical Technology, 2nd Edition, Volume 17, pp. 168-209, Intersciences Publisher, New York (1967).

The complex nature of the bath associated with the spinning of rayon requires extensive water treatment facilities. The mineral salts, such as zinc chloride, are precipitated out as sludges. These sludges constitute the main waste stream from rayon spinning and may contain leachable metal ions.

Other waste streams that are generated consist of off-grade material which is discarded or returned to the head of the viscose production stream.

3.2.5.5 Cellulose Acetate And Triacetate Spinning

Cellulose acetate and cellulose triacetate fibers are produced by a dry spinning process. In this process, cellulose acetate or triacetate, prepared by the process described in section 3.2.4.2, is dissolved in a solvent to form a dope.

- In the case of cellulose acetate, the solvent used for the manufacture of the dope is acetone.
- In the case of triacetate, the best solvent is a mixture of methanol and methylene chloride.

The dope is then spun through a spinneret, as shown in Figure II-20.

The solvents are evaporated from the spun material by means of a hot air stream and adsorbed on carbon. The evaporated solvent is regenerated by steam stripping of the saturated carbon followed by distillation. No waste stream is generated by solvent recovery. The only further processing step is reported to be fiber lubrication.

* * *

The wastes associated with spinning operations are shown in Table II-39.

TABLE II-39

SUMMARY OF WASTE FACTORS IN THE SPINNING OPERATIONS AS A PERCENT OF TOTAL PRODUCTION -- SICs 2823 and 2824

		Waste Factors As A Percent of Total Production			
Product	Method	Off-Grade Product	Waste Water Sludges	Finishing Oils	Others
Polyester	Melt	4.0	None Reported	0.7	Sand Filter 0.02
Polyamides					
Nylon 6	Melt	4.0	None Reported	None Reported	Polymer 1.0
Nylon 6,6		0.5	None Reported	0.17	Lube Oil 0.07
Acrylics	Wet	5.0	20.0(1)(3)	Not individually reported	-
Cellulose Acetate	Dry Spinning	0.2	None Reported(2)	-	-
Rayon	-	-	20.0(3)	-	-

---

(1) This represents a sludge production typical of a salt solution process.

(2) A considerable array of products was manufactured at the sites inspected, and there was no way to separate the contribution of the waste streams to waste treatment sludges.

(3) These streams are designated potentially hazardous.

Source: Foster D. Snell, Inc., analysis of industry interviews and literature information.

4. WASTE CHARACTERIZATION FOR THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY

For the purpose of waste characterization, no valid reason exists to maintain the SIC segmentation of SIC 282. A more reasonable segmentation is between the polymerization and the spinning operations since these topics are more descriptive of the actual conditions in the industry.

The previous section described the processes used and waste streams generated in the segments of SIC 282. The present section:

- Identifies and quantities general waste streams found in our industrial analysis through field visits, interviews and literature studies.
- Pinpoints the streams which have been found to be potentially hazardous.
- Quantifies the wastes for the years 1974, 1977 and 1983.

Qualification of waste streams were presented in Table II-37 for the polymerization operations and in Table II-39 for the spinning operations.

4.1 Waste Stream Characterization In Polymerization Operations

The identification and quantification of the waste streams, particularly in an industry group like SIC 282, is complicated by several factors. Some of these factors are as follows:

- Location of the production facilities -- e.g., single or integrated, and, if integrated, with that
- Relative importance of the process at a given location of the production facilities
- Unquantifiable and variable distribution of products among various production processes -- e.g., emulsion and solution SBR
- Unquantifiable and variable distribution of raw materials in such groups as epoxy, alkyds, polyurethanes, silicones.

Another important factor is the presence of two types of waste streams:

- Well-defined waste streams bearing a fairly constant quantitative relationship to the production volume, e.g., still bottom
- Fortuitous waste streams, characterized by a lack of consistent magnitude, composition, and dependency on extraneous factors, e.g., product changes, human errors, instrument failures.

The field study indicated that the fortuitous waste streams constitute the bulk of the streams, both in number and degree of importance. For instance, it was found that a very important waste stream was that of the irrecoverable off-grade product. The sources of this stream include ends and beginnings of runs, reactor cleanings, spillages, and production upsets.

Further complicating the characterization of some waste streams is the highly proprietary nature of some of the materials involved. In certain product groups (e.g., alkyds epoxy resins, acrylics, and modacrylics), the monomers themselves are proprietary. Almost invariably the exact nature of the catalysts cannot be divulged. Spinning bath compositions are also proprietary.

Within these restrictions, a review of the individual waste streams reported by the interviewees during the field visits is presented in the following paragraphs. The order of presentation is according to decreasing production volume of the particular group of polymers. Subcategories (e.g., polyvinyl acetates) are discussed with the main group, regardless of their individual production levels.

4.1.1 Polyesters

The bulk of polyester production is for use in the fiber industry. Much of the production is captive.

The polyesters most widely used are glycol terephthalates, which polymerize to polyethylene terephthalate with production of ethylene glycol as a by-product (Section 3.2.2.3 Figure II-10; Process Flow Diagram). The ethylene glycol is either processed at the polymerization site or returned to the supplier. In many instances, the primary reactant may be dimethyl terephthalate, in which case a by-product of methanol is produced by transesterification. Usually, this also constitutes a valuable stream which is returned to the supplier.

The literature(1) indicates the use of acetates of cobalt, manganese or cadmium as catalysts. However, the published flow diagrams do not involve a catalysts removal step, nor have any of the interviewees reported such a step. Wastewater treatment facilities are incorporated at most production locations and the metallic ions associated with the process may appear in the sludges.

Some manufacturers indicate the presence in their solid wastes of large quantities of zinc compounds. However, zinc chloride is used as a solution agent for certain types of wet spinning operations, and this may constitute the largest source of zinc ion. It is to be noted also that polyesters, as esters, are readily hydrolyzed so that depolymerization of off-grade waste products are returned to production.

Other wastes include off-grade products still bottoms, waste oils and unreacted terphthalic acid.

4.1.2 Polyamides

The waste stream from Nylon 6 production (Section 3.2.2.2, Figure II-8) consists of manganese hydroxide mud from purification of the recovered caprolactam stream and the still bottoms from caprolactam distillation.

The main waste stream from Nylon 6.6 (Section 3.2.2.2, Figure II-9) production is the spent carbon from the decolorization step. Another stream contributed to by this operation is the biological sludge formed as part of the biological degradation of hexamethylene diamine, one of the starting materials. Off-grade products may account for 3 Kg/KKg of production (0.3%).

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(1) Kirk-Othmer, *Encyclopedia of Chemical Technology* (2nd Edition), Vol. 16.

4.1.3 Acrylics And Modacrylics

In acrylic production (Section 3.2.2.1, Figure II-7), the main waste stream (agglomerate wastes) results from filtration after the polymerization reaction has taken place. The waste can contain large particulates of the polymer referred to as gels or "fish eyes." Monomer recovery still bottoms are another source of waste. These wastes are aqueous and are treated in the wastewater treatment facilities. They may contribute oligimers to the wastewater sludge.

The operation at one specific plant is said to involve a moderately toxic metal ion which is precipitated as a primary sludge. To disclose the ion or the operation would, however, be contrary to the competitive interests of the interviewee.

4.1.4 Low Density Polyethylene

The production technology of this product (described in Section 3.2.1.2.2) is reasonably uniform. The only waste streams identified are:

- Spent lubricating oils from the compressors, which may be found in other polymerization and spinning processes

- Oligomers from the monomer recovery

- Off-grade products, which may amount to 1.0% (10 Kg/KKg of production.

The production does not involve the use of identifiable catalysts.

4.1.5 High Density Polyethylene

The variation of the processes used in the production of polyethylene resins contributes to the difficulty in quantifying the waste streams. It is known that the bulk of the high density polyethylene is still manufactured by variants of two solution processes: the Phillips process and the Ziegler process (Section 3.2.1.3. Figures II-4, II-5). However, no quantitative data can be obtained as to the production distribution among the two processes because such information would be proprietary. Yet, there are very significant differences in the waste streams produced by each process.

To complicate matters further, a new variant of these processes, the particle form process (Section 3.2.1.3.3., Figure II-6) has recently been introduced. From the standpoint of waste streams, the most important aspect of this latter process is that there is no catalyst removal step. In the Ziegler process, an aqueous catalyst removal step is involved which eventually produces aluminum and titanium oxides. In the Phillips process, the catalyst is separated as a finely divided solid consisting of a ceramic-type mixture of alumina and chromium oxides. Because of the ceramic nature of the catalyst, there is no chromium leachate.

In addition to these streams, there are off-grade products and, in the Ziegler process, bottoms from aqueous alcohol recovery. This latter stream goes to the wastewater treatment facilities where it contributes to the production of biological sludges.

4.1.6 SBR Rubber

Two methods are used in the production of SBR rubber: The solution polymerization process and the emulsion polymerization process.

If the solution process is used, the washed butadiene stream has to be dried in an absorbent The adsorbent can be regenerated over many cycles; but it must eventually be discarded, and it thereby creates a waste stream. When Ziegler type catalysts are used in the solution process (Section 3.2.1.3., Figure II-5), the typical alumina and titanium dioxide sludges are also produced, constituting another source of wastes.

In the emulsion process (Section 3.2.1.1., Figure II-2), wastewater treatment sludges constitute another waste stream. A waste stream, at certain locations, consists of the alkaline wash used to remove catechol, which stabilizes the butadiene stream. Both emulsion and solution processes contribute to this type of waste stream.

Additional waste streams may be generated where master batching constitutes a significant proportion of the production. These include:

- Carbon black dusts (sometimes in the form of a wet scrubber sludge.)

- Waste additive oils resulting from spillages or production upsets. These are often caught in special traps or pits.

Storage tanks and equipment cleanings also contribute to waste streams, as do off-grade products.

4.1.7 Polyvinyls

Polyvinyl chloride and polyvinyl acetate are the main products in this group. Polyvinyl chloride is produced in greater quantity. The two main processes that are used are suspension or emulsion polymerization and bulk polymerization.

Waste streams generated in suspension or emulsion polymerization of polyvinyl chloride include:

- Off-grade finished product, which can be as high as 2.0% of total production.

- Wastewater sludges, amounting to 11 Kg/KKg of production (1.1%) and possibly including vinyl chloride monomer from reaction cleanings

- Fines from polymer separation

- Sweepings, which can include dusts (although with current OSHA requirements, dust production should be reduced)

- Scrap pellets.

Waste streams constituted in polyvinyl acetate production include off-grade products (discolored resin chunks), which are estimated to be 10 Kg/KKg of production. In addition waste streams may be generated by:

- Still bottoms containing olisomers and vinyl chloride dissolved in vinyl acetate

- Filtered latex waste when polyvinyl acetate is processed as the latex

- Vinyl acetate copolymer.

4.1.8 Polypropylene

Polypropylene is produced by a variety of process variations quite similar to those used for high density polyethylene (Section 3.2.1.3.2, Figure II-5). The general waste streams associated with polypropylene and high density polyethylene are similar. However, as with high density polyethylene, the variability contributes to the difficulty in quantifying the waste streams.

Off-grade products are estimated to account for 0.5% of total production. Still bottoms and waste oils may account for 10 Kg/KKg of production, thus constituting another source of waste. Amorphorous polypropylene may, under adverse economic conditions, constitute a portion of the still bottoms. However, this material can be used for certain applications, e.g., adhesives.

In those plants using variations of the Ziegler process, an aluminum hydroxide waste stream is generated. Newer variations (particle form process, Section 3.2.1.3.3., Figure II-6) utilize more efficient catalysts that can be left and incorporated into the finished product. Other sources of waste streams include:

- Fines water streams and dust collectors
- Wastewater treatment sludges
- Aqueous wastes with polymer solids
- Scrap flakes.

4.1.9 Other Synthetic Rubbers

The waste streams encountered in production of such rubbers as neoprene, EPM, EPDM and polybutadiene are similar to those encountered in SBR production (Section 3.2.1.1., Figure II-2). These would include:

- Wastewater treatment sludges
- Scrap
- Fines in sludge water
- Fines from dust collectors.

In addition, spent adsorbent and spent catalyst constitute a waste stream with these other synthetic rubbers. At one location, vanadium waste stream is produced from the used catalyst; however, the metal is reduced to 1 ppm when diluted in other plant wastewaters. The still bottom and waste oil streams are estimated to be 60 Kg/KKg of production of neoprene.

4.1.10 Phenolic Resins

The phenolic resins (Section 3.2.3.1.1., Figure II-11) present waste streams which deserve considerable attention. Water is generated during the reaction and is distilled off from the reactors. There is entrainment of oligomers, unreacted phenols, and other organic components in this very significant water stream. This source of waste is estimated (on a wet basis) to be about 500 Kg/KKg of product produced with an organic content of 5% to 15%. These wastes also contain large amounts of phenols, substituted phenols and cresols in addition to other organic components. As previously mentioned in Section 3.2.3.1., no satisfactory method of handling this waste stream has been devised. These wastes are essentially hazardous and are discussed in Section 4.3.

Other significant waste stream sources are composed of off-grade product (which is estimated to be 8 Kg/KKg of product produced) and wastewater sludge which is estimated to be 60 Kg/KKg and which may contain partially unreacted product.

4.1.11 Amino Resins

The process flow diagram for amino resins was previously presented in section 3.2.3.2. Figure II-12). Waste stream identification includes:

- Off-grade material constituting an estimated 10 Kg/KKG of product produced
- A significant proportion of production in still bottoms and waste oils (42 Kg/KKg)
- Filter cake from the production of liquid resins.

In addition, wastes are generated from bad production batches, usually caused by unreacted formaldehyde. One solvent (methanol) may also be part of wastes produced, depending upon the efficiency of the system.

4.1.12 Coumarone-Indene

These resins (Section 3.2.3.3, Figure II-13 are almost insignificant in terms of production volumes as compared to the large volume of polyethylenes in vinyl chlorides. They are practically free of waste streams. The petroleum distillates may be utilized as boiler fuel. Still bottoms (lower-grade material) are sold at a discount.

The major waste stream consists of spent clay (36 Kg/KKg of production). This results from those processes that use boron trifluoride as a catalyst during the polymerization step. Attapulgite clay and lime are used to remove boron/fluorine and spent catalyst. The resulting spent mixture is filtered out and consists of about 60% clay/calcium hydroxide and 40% organic residue. The boron trifluoride or its decomposition products are likely to be in this waste stream.

4.1.13 Alkyd Resins

The products containing alkyd resins are extremely numerous and vary greatly. Therefore, generalizations based on the necessarily limited field investigations are of limited validity. Section 3.2.3.5 previously described general production (Figure II-15).

Wastes usually associated with alkyd resin production include:

- Off-grade product (1 Kg/KKg of production)
- Sweepings from warehouse wastes.

Bulk shipping of monomers in a production facility is the exception rather than the rule. Therefore, when solid, these monomers contribute significantly to the composition of warehouse wastes and represent a measurable fraction (0.1 Kg/KKg of production) of the production volume.

4.1.14 Epoxy Resins

These resins (Section 3.2.3.4, Figure II-14) are condensation products of epichlorohydrin, bisphenol A and other co-monomers. The observations made for the alkyds (in Section 4.1.13) apply equally well to this group of products.

The identifiable, but highly variable waste streams, could not be quantified but include:

- Off-grade products
- Off-grade raw materials
- Still bottoms
- Waste solvents (xylene).

4.1.15 Polyurethanes

The bulk of the production (described in Section 3.2.3.6, Figure 16) is performed at the manufacturing site where end-use products are made. Prepolymers are centrally manufactured in some plants in equipment which is sometimes even used for the manufacture of other groups of products, e.g., alkyds or epoxy. This equipment consists of batch reactors equipped with condensers which can work either as reflux or distillation condensers. The waste streams consist of washings, filter cakes, oligomers and solvents.

4.1.16 Silicones

As previously discussed in production processing of silicones (Section 3.2.3.7, Figure II-17), specific quantification of waste streams in silicone production is difficult. The waste streams include off-grade products which constitute an estimated 54 Kg/KKg of production. Still bottoms and raw material waste oils are estimated at a 58 Kg/KKg of production. Other estimated wastes include spent adsorbent and scrap (33 Kg/KKg of production).

Additional sources of waste stream generation include:

- Waste solvent from silicone resin production
- Filter cake used in a filtering step of silicone resin production.

4.1.17 Cellulosic

The waste streams from the viscose rayon process are essentially aqueous solutions, semisolids (hemicellulose), fine slurries and sludges (Section 3.2.4.1, Figure II-18).

In the production of acetate and triacetates (Section 3.2.4.2, Figure II-19), the waste streams also include recovered acetic acid streams, which are usually reused in process or recovered for other purposes. Heavy concentrations of magnesium sulfate salts are also encountered. Cellulosic sludges are also produced.

4.2 Waste Stream Characterization In Spinning Operations

The spinning processes produce essentially three types of wastes (Figure II-20):

- Various types of off-grade products at various stages of manufacture
- Sludges from the treatment of waste baths
- Still bottoms from solvent recovery.

In the following paragraphs, the specific nature of the waste streams associated with the various fibers and the various spinning methods are discussed in more detail. As usual, the discussion follows the order of decreasing importance in terms of weight processed.

4.2.1 Polyester Spinning Wastes

Because these products are generally spun from the molten state and because the material which has to be discarded for one reason or another can either be remelted or depolymerized, off-grade product wastes are insignificant. The waste sand, where sand filtration is used ahead of the spinneret, constitutes an insignificant stream.

A stream of waste finishes exists in some operations. This stream has been reported as being recovered in oil traps at a wastewater treatment facility.

Finally, a stream of triethylene glycol is sometimes produced from cleaning operations. It can usually be recovered.

4.2.2 Nylon Spinning

Nylon is spun from the molten state. The only waste streams from the spinning and finishing operations are said to be irrecoverable waste fiber and yarn, biodegradable and non-biodegradable finishing oils. In addition, a small stream of lubricant from various pieces of equipment is encountered in some installations.

4.2.3 Acrylic And Modacrylic Spinning

From the standpoint of waste generation, at least three widely different methods of spinning acrylics have been reported. Two methods are variants of the wet spinning process and one is a dry spinning method. The significant factor in the wet spinning process is the type of solvent used to form the dope. In certain instances, the acrylic material is dissolved in high concentrations of metal salts in water. In another variant, a water miscible solvent is used. Obviously, the wastes are quite different, depending on what process is used.

Large amounts of sludges containing metal ions have been acknowledged at several locations. A frequently mentioned ion has been zinc. On the other hand, some other installations (or some lines in the same plant) use different processes, e.g., dry spinning. In this case, a volatile solvent is used rather than a metal salt solution, still bottoms may be obtained and also biological sludges, if there is a biological treatment. It is difficult, therefore, to generalize the waste streams since distribution of the production across the three methods is not known. The dry spinning method is used for some modacrylics and is said not to produce any significant waste other than off-grade material.

4.2.4 Acetate And Triacetate Spinning

The spinning of acetate and triacetate fiber involves the dry spinning methods and exhibits the characteristic waste streams of this method. The main waste stream is off-grade material which can be hydrolyzed and returned to process.

4.2.5 Rayon Spinning

The spinning of rayon involves complex baths which have to be periodically readjusted or cleaned. Considerable wastewater containing high concentrations of all kinds of salts, organic and mineral compounds is generated. Extensive wastewater treatment is required with production of large amounts of sludges, which may contain leachable metallic ions.

In addition, warehouse dusts and sweepings may be generated in the handling of chemicals constituting the baths or added to the dope formulation. The use of such materials as diamines and dithiocarbamates has been reported. Large amounts of zinc salts are also reported to be used.

4.3 Potentially Hazardous Waste Streams And The Criteria For Their Classification

This section addresses streams which are designated as potentially hazardous when rated against the criteria of toxicity, flammability, etc. The streams identified as potentially hazardous include:

- SIC 2821 -- Plastic Resins
  - Wastes from phenolic resin production
  - Amino resin waste streams
  - Antimony and manganese catalyst waste from polyester production(1)
  - Still bottoms from solvent or monomer recovery in:
    - ABS-SAN resins
    - Polystyrene
    - Polypropylene
    - Silicone
  - Warehouse dusts from alkyd production

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(1) Polyester waste stream is listed under SIC 2821 to reflect the fact that the stream is generated at the polymerization step. It is understood that a considerable amount of polyester production occurs in SIC 2824.

- SIC 2822 - Synthetic Rubber
  - Still bottoms from solvent or monomer recovery in
    - SBR via the solution process
    - Polybutadiene rubber
    - Neoprene rubber
- SIC 2823 -- Cellulosic Manmade Fibers
  - Diamine and dithiocarbamate dusts and powders from rayon production
  - Wastewater treatment sludges from rayon production
- SIC 2824 -- Non-Cellulosic Manmade Fibers
  - Zinc containing sludges from the spinning of acrylics and modacrylics.

By and large, company personnel in the plants visited are acutely aware of the potentially hazardous nature of the streams identified by the study team.

4.3.1 Criteria For The Classification Of Waste Streams As Potentially Hazardous In The Plastic Materials And Synthetics Industry

A potentially hazardous waste stream refers to any waste or combination of wastes which pose a substantial present or potential hazard to human health or living organisms because such wastes are suspected of being:

- Toxic (including carcinogenic)
- Flammable or explosive
- Corrosive or reactive
- Biologically magnified or persistent.

These types of hazards represent four out of five basic hazardous characteristics of wastes which were established in EPA's report to Congress, Disposal of Hazardous Wastes. The fifth characteristic, radioactivity, does not apply to the wastes generated by SIC 282.

According to the mandate given to Foster D. Snell, Inc., by EPA, detailed original toxicological, chemical and biological investigations to determine the potential for hazard creation by the literally thousands of substances in these industries which may become wastes was not a requirement. Instead, reliance on published sources which are compendia of much of the required information was the preferred approach. The sources chosen were:

- Reference 1 -- Dangerous Properties of Industrial Materials (4th Ed.) N. Irving Sax (New York: Van Nostrand Reinhold Company, 1974).
- Reference 2 -- Clinical Toxicology of Commercial Products (3rd Ed.) Gleason, Gosselin, Hodge and Smith (Baltimore: The Williams & Wilkins Co., 1969).
- Reference 3 -- A Study of Hazardous Waste Materials, Hazardous Effects and Disposal Methods, Bo[illegible]llen Applied Research, Inc., United Stat[illegible]ironmental Protection Agency (Contract #68-03-0032)(Cincinnati, Ohio: 1972).

For the purposes of this study, oral toxicity was accepted as the basis for defining a toxic substance because more data are generally available to support published conclusions based on this parameter. Hazardous rating scales from these publications are presented in Appendix A, Methodology. Information from these sources were supplemented by the companies interviewed and judgments of the study team. Chemical analysis of spc[illegible]amples of wastes obtained from industry sources aided in the quantification and substantiation of some of the streams classified as potentially hazardous.

During the course of the study, the following hazardous constituents were found to be in the wastes:

- Phenols
- Antimony, zinc and manganese ions
- Aromatic and chlorinated hydrocarbons
- Diamines and dithiocarbamate dusts
- Maleic anhydrides.

The discussion below briefly presents information on why these substances are considered to be hazardous. The next section, 4.3.2, relates the substances identified to specific waste streams generated by this industry.

4.3.1.1 Phenols

Phenols have been assigned (1,2,3) a high hazard rating. That is, death or permanent injury may occur after very short exposure to small quantities. In acute phenol poisoning, the main effect is on the central nervous system; chronic poisoning, following prolonged exposures to low concentrations of the vapor or mists, results in digestive disturbance (vomiting, difficulty in swallowing, extensive salivation, diarrhea, loss of appetite), nervous disorders and skin irritations. Chronic poisoning may terminate fatally in cases with extensive damage to the kidneys or liver. Phenols have been assigned a moderate hazard rating(3) for flame, explosion and reaction in soil.

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(1) Dangerous Properties of Industrial Materials (4th Ed.) N. Irving Sax (New York: Van Nostrand Reinhold Company, 1974).

(2) Clinical Toxicology of Commercial Products (3rd Ed.) Gleason, Gosselin, Hodge and Smith (Baltimore: The Williams & Wilkins Co., 1969).

(3) A Study of Hazardous Waste Materials, Hazardous Effects and Disposal Methods, Booz Allen Applied Research, Inc., United States Environmental Protection Agency (Contract #68-03-0032) (Cincinnati, Ohio: 1972).

4.3.1.2 Antimony Zinc And Manganese Ions

Antimony compounds have been assigned highly(1) and extremely(2) toxic ratings. In humans, complaints referable to the nervous system have been reported. Animals exposed to fumes of antimony oxide have developed such symptoms as pneumonitis, fatty degeneration of the liver, polymorphonuclears and damage to the heart muscles.

Zinc salts have been assigned(3) a toxicity rating of very toxic. Toxicity and toxic actions are like those of copper salts. They produce irritation or corrosion of the alimentary tract with pain, emisis, etc. Zinc exhibits its greatest toxicity towards fish and aquatic organisms. In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/liter have been reported to be lethal. The toxicity of zinc salts is increased at lower concentrations of dissolved oxygen in about the same proportion as for lead, copper and phenols, e.g., the lethal concentration at 60% saturation of dissolved oxygen is only about 0.85 that at 100% saturation.

Manganese salts are regarded(2) as being moderately toxic to humans. As with industrial exposure to dust, nervous symptoms predominate. In ground water subject to reducing conditions(4) manganese can be leached from the soil and occur in high concentrations. Many organisms are capable of concentrating manganese in their bodies to many times above the concentration in sea water.

4.3.1.3 Aromatic And Chlorinated Hydrocarbons

Aromatic hydrocarbons are regarded(2) to be very toxic and in many cases quite flammable. These materials are toxic by all portals of entry. Some aromatic hydrocarbons are suspected of being carcinogenic agents. Chlorinated hydrocarbons are under suspicion of being carcinogenic. Chlorinated solvents are liver and kidney poisons and central nervous depressants(2).

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(1) Dangerous Properties of Industrial Materials (4th Ed.) N. Irving Sax (New York: Van Nostrand Reinhold Company, 1974).

(2) Clinical Toxicology of Commercial Products (3rd Ed.) Gleason, Gosselin, Hodge and Smith (Baltimore: The Williams & Wilkins Co., 1969).

(3) A Study of Hazardous Waste Materials, Hazardous Effects and Disposal Methods, Booz, Allen Applied Research, Inc., United States Environmental Protection Agency (Contract #68-03-0032) (Cincinnati, Ohio: 1972).

(4) Water Quality Criteria, McKee, Y.E., H.W. Wolf, Eds., Resources Agency of California State Water Quality Control Board.

4.3.1.4 Diamines And Dithiocarbamates

Phenylenediamine, for example, is regarded(1) as being very toxic. Indeed, it is a suspected cause of bladder tumors in "aniline" workers.

Dithiocarbamates are also regarded as being very toxic. Zinc dibutyldithiocarbamate is a recognized(2) carcinogen. The diethyl and dimethyl analogues are recognized(2) as being carcinogenic, as well.

4.3.1.5 Maleic Anhydrides

Maleic anhydride, when reacted with water, will produce heat. When heated, it will emit toxic fumes. In addition, its acute local and systemic effects are rated high for humans.

4.3.2 Potentially Hazardous Waste Streams

The following discussion presents those waste streams which are potentially hazardous and the rationale behind their classification, case by case.

Foster D. Snell,Inc.,analyzed waste samples obtained from industry sources to spot check the assumptions made as to components and concentrations constituting the wastes. The results of the analytical program and the methodology employed in the analysis of wastes are presented in Appendix B.

4.3.2.1 Wastes From Phenolic Production

The wastes from phenolic production present themselves in the form of: solutions containing a large amount of water with variable concentrations (5% to 15%) of the organic materials, specifically phenols and discarded off-grade, partly unreacted products also containing excess phenols. This waste stream has high toxicity because phenol compounds are present.

4.3.2.2 Wastes In Amino Resins

In at least one instance, the disposal of partly unreacted amino resins has been mentioned. This stream is fortuitous in nature, resulting from equipment breakdown or human error. However, its occurrence over a period of time cannot be discounted.

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(1) Clinical Toxicology of Commercial Products (3rd Ed) Gleason, Gosselin, Hodge and Smith (Baltimore: The Williams & Wilkins Co., 1969).

(2) Dangerous Properties of Industrial Materials (4th Ed.) N. Irving Sax (New York: Van Nostrand Reinhold Company, 1974).

The toxicity of the streams results from excess unreacted formaldehyde. In addition, an overhead stream of formaldehyde contaminated methanol is produced. This stream is considered hazardous because of the toxicity of formaldehyde combined with the high flammability of the mixture.

4.3.2.3 Antimony And Manganese Catalysts In Polyester

The literature indicates the use of acetates of cadmium, cobalt and manganese in polyester production. In addition, the antimony-containing catalyst has also been mentioned in the industry interviews. A stream of waste catalysts (as distinct from a potential catalyst sludge, which was not mentioned in any interview) originates from the very dust control equipment installed to protect the workers handling this material. The toxicity of this stream results from the chemical species -- antimony, manganese or cadmium.

4.3.2.4 Still Bottoms

Still bottoms are those fractions obtained from rectification columns used to purify or separate solvents. There are two types of still bottoms: aqueous and non-aqueous.

As a rule, the aqueous still bottoms are handled in wastewater treatment facilities where they do not present any particular problem. Sometimes these aqueous still bottoms may contain immiscible oils which are separated at the treatment facilities.

The non-aqueous still bottoms may be potentially hazardous by reason of their flammability. In addition, they may be considered suspect if they contain significant amounts of polycyclic aromatics. For these reasons, it would appear that the still bottoms generated in the manufacture of the products listed below are potentially hazardous:

- ABS-SAN
- Polystyrene
- Polypropylene
- SBR (solution process)
- Polybutadiene
- Neoprene.

4.3.2.5 Waste Solvents In Silicone Resin Production

The production of silicone resin is carried out in only five plants in the United States. The technology is perhaps the most proprietary of those encountered in the whole industry (with the possible exception of spinning).

Improper disclosure of confidential information may result from detailed discussion of this item. Special disposal of these solvents has been reported which, by implication, classifies them as potentially hazardous wastes.

4.3.2.6 Hazardous Wastes In Rayon Production

Recently, production of rayon in the United States has declined considerably. Economic considerations have been always mentioned for the closure of production facilities. Nevertheless, another potential cause of this trend may have been the impossibility of meeting effluent guidelines for wastewater. Thus, the classification of some of the streams from the rayon process as potentially hazardous may be academic. Two areas of potentially hazardous waste include:

- Dusts or spills from the handling of dithiocarbamates and ethylene diamine, which have been mentioned as additives

- Highly metal contaminated wastewater treatment sludges.

Considerable amounts of zinc have been reported in the wastewaters. This, in turn, would be precipitated as zinc oxide in the sludge. Zinc oxide is highly leachable and, thus, the sludges are potentially hazardous. An amount of 25-50 Kg/KKg of product (dry weight) has been reported for rayon production sludges.

4.3.2.7 Hazardous Wastes In Acrylic And Modacrylic Production

In this production, a considerable amount of zinc-bearing wastewater sludges has been reported.

4.4 Waste Quantification For The Years 1974, 1977 And 1983 (Plastic Materials And Synthetics Industry)

In this portion of the report, estimated total and potentially hazardous waste quantities for the industry are presented for the year 1974, and projections are made for 1977 and 1983. The data is based on the results of industry interviews, literature search, the analytical procedures carried out on actual waste samples obtained from industry sources and the INFORUM input/output model.

The required information is presented in a series of tables:

- Table II-40 -- Estimated 1974 Geographic Distribution Of Wastes For The Major Polymerization Operations
- Table II-41 -- Estimated 1974 Geographic Distribution Of Wastes For The Spinning Operations
- Table II-42 -- Total Estimated Wastes For The Years 1974, 1977 And 1983.

The following paragraphs discuss the rationale used in developing these tables.

4.4.1 Total Wastes

Total wastes for the industry in 1974 were developed by multiplying the sum of the waste factors for each of the products manufactured (found in Tables II-37 and II-39) by the production values for these products.

- Table II-40, provides the total wastes by product for 1974 for polymerization operations.
- Table II-41, does the same for spinning operations.

The values presented in Tables II-40 and II-41 were added together to obtain the 1974 values presented in Table II-42, which summarizes the wastes for SIC 282 as an aggregate.

TABLE II-40 (1)

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION OF WASTES FOR THE MAJOR POLYMERIZATION OPERATIONS OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY--SIC 282 (6) (WET BASIS) (KKg/YEAR)

		POLYESTERS		POLYAMIDES[2]	
		Total Wastes	Potentially[1] Hazardous Wastes	Total Wastes	Potentially[3] Hazardous Wastes
IV	Alabama				
X	Alaska				
IX	Arizona				
VI	Arkansas	(D)			
IX	California	2,542			
VIII	Colorado				
I	Connecticut	(D)			
III	Delaware	(D)			
IV	Florida	1,581			
IV	Georgia			(D)	
IX	Hawaii				
X	Idaho				
V	Illinois	124			
V	Indiana	(D)			
VII	Iowa				
VII	Kansas				
IV	Kentucky	(D)			
VI	Louisiana	(D)		(D)	
I	Maine				
III	Maryland				
I	Massachusetts			N.A.	
V	Michigan	1,023			
V	Minnesota				
IV	Mississippi				
VII	Missouri	744			
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire			(D)	
II	New Jersey	775			
VI	New Mexico				
II	New York	248			
IV	North Carolina	32,488		645	
VIII	North Dakota				
V	Ohio	(D)			
VI	Oklahoma	(D)			
X	Oregon	31			
III	Pennsylvania	620			
I	Rhode Island			(D)	
IV	South Carolina	29,450		4,140	
VIII	South Dakota				
IV	Tennessee	23,870		2,328	
VI	Texas	465		N.A.	
VIII	Utah				
I	Vermont				
III	Virginia			2,328	
X	Washington	(D)			
III	West Virginia			(D)	
V	Wisconsin	(D)			
VIII	Wyoming				
	TOTAL	87,340		9,630	
Region	I	(D)		(D)	
	II	1,023			
	III	620		2,328	
	IV	87,389+		7,113+	
	V	1,147+			
	VI	465+		N.A.	
	VII	744			
	VIII				
	IX	2,542			
	X	31+			

Notes

(D) = Withheld to avoid disclosing figures for individual companies.

(1) Negligible, less than 10 KKg for entire country

(2) Nylon 6 and Nylon 6,6

(3) No potentially hazardous wastes

Source: Foster D. Snell, Inc., compilations and analysis of waste streams reported during the industry survey.

TABLE II-40 (2)

POLYETHYLENES

		HIGH DENSITY		LOW DENSITY	
		Total Wastes	Potentially Hazardous Wastes(1)	Total Wastes	Potentially Hazardous Wastes(1)
IV	Alabama				
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California			(D)	
VIII	Colorado				
I	Connecticut				
III	Delaware				
IV	Florida				
IV	Georgia				
IX	Hawaii				
X	Idaho				
V	Illinois			(D)	
V	Indiana			(D)	
VII	Iowa	(D)		(D)	
VII	Kansas				
IV	Kentucky				
VI	Louisiana	(D)		5,401	
I	Maine				
III	Maryland				
I	Massachusetts				
V	Michigan				
V	Minnesota				
IV	Mississippi				
VII	Missouri				
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey				
VI	New Mexico				
II	New York				
IV	North Carolina				
VIII	North Dakota				
V	Ohio				
VI	Oklahoma				
X	Oregon				
III	Pennsylvania				
I	Rhode Island				
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas	6,755		8,040	
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington				
III	West Virginia				
V	Wisconsin				
VIII	Wyoming				
	TOTAL	9,058		29,964	
Region	I				
	II				
	III				
	IV				
	V			(D)	
	VI	6,755+		13,441	
	VII	(D)		(D)	
	VIII				
	IX			(D)	
	X				

Notes
(D) = Withheld to avoid disclosing figures for individual companies.
(1) No potentially hazardous wastes

Source: Foster D. Snell, Inc., compilations and analysis of waste streams reported during the industry survey.

TABLE II-40 (3)

		POLYVINYL CHLORIDE		POLYPROPYLENE		
		Total Wastes	Potentially Hazardous Wastes (1)	Total Wastes	Potentially Hazardous Wastes	Flammable Aliphatic Still Bottoms
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California	(D)				
VIII	Colorado					
I	Connecticut					
III	Delaware	(D)		(D)	(D)	(D)
IV	Florida	(D)				
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois	(D)				
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky	(D)				
VI	Louisiana	8,215		(D)	(D)	(D)
I	Maine					
III	Maryland	(D)				
I	Massachusetts	5,580				
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey	6,913		(D)	(D)	(D)
VI	New Mexico					
II	New York	(D)				
IV	North Carolina					
VIII	North Dakota					
V	Ohio	8,060				
VI	Oklahoma	(D)				
X	Oregon					
III	Pennsylvania	(D)				
I	Rhode Island	(D)				
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	9,765		8,399	4,940	4,940
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia	3,317		(D)	(D)	(D)
V	Wisconsin					
VIII	Wyoming					
	TOTAL	68,572		17,442	10,260	10,260
	Region I	5,580+				
	II	6,913+		(D)	(D)	(D)
	III	3,317+		(D)	(D)	(D)
	IV	(D)		8,399+	4,940+	4,940+
	V	8,060+				
	VI	17,980+				
	VII					
	VIII					
	IX	(D)				
	X					

Note:
(D) = Withheld to avoid disclosing figures for individual companies.

(1) No potentially hazardous wastes

Source: Foster D. Snell, Inc. compilations and analysis of waste streams reported during the industry survey.

TABLE II- 40(4)

		ABS-SAN			POLYSTYRENE		
		Total Wastes	Potentially Hazardous Wastes	Aromatic Still Bottoms	Total Wastes	Potentially Hazardous Wastes	Aromatic Still Bottoms
IV	Alabama						
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	(D)	(D)	(D)	3.600	3.000	3.000
VIII	Colorado						
I	Connecticut	(D)	(D)	(D)	(D)	(D)	(D)
III	Delaware						
IV	Florida						
IV	Georgia						
IX	Hawaii						
X	Idaho				4.116	3.430	3.430
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky	(D)	(D)	(D)			
VI	Louisiana	(D)	(D)	(D)			
I	Maine						
III	Maryland						
I	Massachusetts				4.512	3,760	3,760
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri				(D)	(D)	(D)
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	(D)	(D)	(D)			
VI	New Mexico						
II	New York						
IV	North Carolina				(D)	(D)	(D)
VIII	North Dakota						
V	Ohio	(D)	(D)	(D)	5.488	4,540	4.540
VI	Oklahoma						
X	Oregon						
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas				(D)	(D)	(D)
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington						
III	West Virginia	(D)	(D)	(D)			
V	Wisconsin						
VIII	Wyoming						
	TOTAL	15.840	2,200	2.200	22.128	18.440	18.440
	Region I	(D)	(D)	(D)	4.512+	3.760+	3.760+
	II	(D)	(D)	(D)			
	III	(D)	(D)	(D)			
	IV	(D)	(D)	(D)	(D)	(D)	(D)
	V	(D)	(D)	(D)	5,488	4,540	4,540
	VI	(D)	(D)	(D)	(D)	(D)	(D)
	VII				(D)	(D)	(D)
	VIII						
	IX	(D)	(D)	(D)	3,600	3,000	3,000
	X				4,116	3,430	3,430

Notes

(D) = Withheld to avoid disclosing figures for individual companies.

Source Foster D. Snell, Inc., compilations and analysis of waste streams reported during the industry survey.

TABLE II- 40 (5)

		ACRYLICS		SBR		
		Total Wastes	Potentially Hazardous Wastes (1)	Total Wastes	Potentially Hazardous Wastes (2)	Aromatic Still Bottoms
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California			(D)	(D)	(D)
VIII	Colorado					
I	Connecticut			1,050	252	252
III	Delaware			(D)	(D)	(D)
IV	Florida					
IV	Georgia			(D)	(D)	(D)
IX	Hawaii					
X	Idaho					
V	Illinois			(D)	(D)	(D)
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky	(D)		(D)	(D)	(D)
VI	Louisiana	(D)		11,163	2,679	2,679
I	Maine					
III	Maryland					
I	Massachusetts			(D)	(D)	(D)
V	Michigan			(D)	(D)	(D)
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York			(D)	(D)	(D)
IV	North Carolina			(D)	(D)	(D)
VIII	North Dakota					
V	Ohio			8,175	2,202	2,202
VI	Oklahoma					
X	Oregon					
III	Pennsylvania			(D)	(D)	(D)
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee			(D)	(D)	(D)
VI	Texas	1,980		23,250	5,580	5,580
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia	(D)				
V	Wisconsin					
VIII	Wyoming					
	TOTAL	2,709		52,910	12,698	12,698
Region	I			1,050+	252+	252+
	II			(D)	(D)	(D)
	III	(D)		(D)	(D)	(D)
	IV	(D)		(D)	(D)	(D)
	V			8,175+	2,202+	2,202+
	VI	1,980+		34,413	8,259	8,259
	VII					
	VIII					
	IX			(D)	(D)	(D)
	X					

Notes
(D) = Withheld to avoid disclosing figures for individual companies.

(1) No potentially hazardous wastes

(2) Value for all wastes is the average for two production processes - solution and emulsion

Source Foster D. Snell, Inc. compilations and analysis of waste streams reported during the industry survey.

TABLE II- 40 (6)

		PHENOLICS			POLYBUTADIENE		
		Total Wastes	Potentially Hazardous Wastes	Aqueous Solution Of Phenol And Formaldehyde	Total Wastes	Potentially Hazardous Wastes	Aliphatic Still Bottoms
IV	Alabama	(D)	(D)	(D)			
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California	34.800	34.800	34.800			
VIII	Colorado						
I	Connecticut	(D)	(D)	(D)			
III	Delaware						
IV	Florida	(D)	(D)	(D)			
IV	Georgia						
IX	Hawaii						
X	Idaho						
V	Illinois	(D)	(D)	(D)	(D)	(D)	(D)
V	Indiana						
VII	Iowa						
VII	Kansas	(D)	(D)	(D)			
IV	Kentucky				(D)	(D)	(D)
VI	Louisiana						
I	Maine						
III	Maryland						
I	Massachusetts	(D)	(D)	(D)			
V	Michigan	(D)	(D)	(D)			
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana	(D)	(D)	(D)			
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey	31.800	31.800	31.800			
VI	New Mexico						
II	New York	64.800	64.800	64.800			
IV	North Carolina	8.600	8.600	8.600			
VIII	North Dakota						
V	Ohio	74.400	74.400	74.400			
VI	Oklahoma						
X	Oregon	24.000	24.000	24.000			
III	Pennsylvania						
I	Rhode Island						
IV	South Carolina						
VIII	South Dakota						
IV	Tennessee						
VI	Texas	31.200	31.200	31.200	869	40	40
VIII	Utah						
I	Vermont						
III	Virginia						
X	Washington	(D)	(D)	(D)			
III	West Virginia						
V	Wisconsin	(D)	(D)	(D)			
VIII	Wyoming						
	TOTAL	366.000	366.000	366.000	1.049	48	48
	Region I	(D)	(D)	(D)			
	II	96.600	96.600	96.000			
	III						
	IV	8.600+	8.600+	8.600+	(D)	(D)	(D)
	V	74.400+	74.400+	74.400+	(D)	(D)	(D)
	VI	31.200	31.200	31.200	869	40	40
	VII	(D)	(D)	(D)			
	VIII	(D)	(D)	(D)			
	IX	34.800	34.800	34.800			
	X	24.000+	24.400+	24.400+			

Notes
(D) = Withheld to avoid disclosing figures for individual companies.

Source Foster D. Snell, Inc. compilations and analysis of waste streams reported during the industry survey.

TABLE II- 40 (7)

		AMINO RESINS				ALKYDS		
		Total Wastes	Potentially Hazardous Wastes	Methanol/Formaldehyde Mix	Formaldehyde Contaminated Waste Products	Total Wastes	Potentially Hazardous Wastes	Maleic and Phthalic Anhydride Contaminated Floor Sweepings
IV	Alabama	385	385	294	70	(D)	(D)	(D)
X	Alaska							
IX	Arizona							
VI	Arkansas	(D)	(D)	(D)	(D)			
IX	California	1,705	1,705	1,302	310	57	5	5
VIII	Colorado					(D)	(D)	(D)
I	Connecticut	(D)	(D)	(D)	(D)			
III	Delaware	(D)	(D)	(D)	(D)	(D)	(D)	(D)
IV	Florida	(D)	(D)	(D)	(D)	8	1	1
IV	Georgia	385	385	294	70	6	1	1
IX	Hawaii							
X	Idaho							
V	Illinois	1,265	1,265	966	230	44	4	4
V	Indiana					8	1	1
VII	Iowa					(D)	(D)	(D)
VII	Kansas							
IV	Kentucky	(D)	(D)	(D)	(D)	10	1	1
VI	Louisiana	(D)	(D)	(D)	(D)			
I	Maine	(D)	(D)	(D)	(D)			
III	Maryland	(D)	(D)	(D)	(D)	10	1	1
I	Massachusetts	275	275	210	50	10	1	1
V	Michigan	385	385	294	70	12	1	1
V	Minnesota					(D)	(D)	(D)
IV	Mississippi	(D)	(D)	(D)	(D)			
VII	Missouri	(D)	(D)	(D)	(D)	13	1	1
VIII	Montana	(D)	(D)	(D)	(D)			
VII	Nebraska							
IX	Nevada							
I	New Hampshire	(D)	(D)	(D)	(D)			
II	New Jersey	2,310	2,310	764	420	51	5	5
VI	New Mexico							
II	New York	660	660	504	120	18	2	2
IV	North Carolina	1,815	1,815	386	330			
VIII	North Dakota							
V	Ohio	1,540	540	1,176	280	25	2	2
VI	Oklahoma							
X	Oregon	1,540	1,540	1,176	280	(D)	(D)	(D)
III	Pennsylvania	1,430	1,430	1,092	260	25	2	2
I	Rhode Island	880	880	672	160			
IV	South Carolina	660	660	504	120	(D)	(D)	(D)
VIII	South Dakota							
IV	Tennessee	(D)	(D)	(D)	(D)	(D)	(D)	(D)
VI	Texas	1,045	1,045	798	190	19	2	2
VIII	Utah					(D)	(D)	(D)
I	Vermont							
III	Virginia	385	385	294	70			
X	Washington	770	770	588	140			
III	West Virginia							
V	Wisconsin	1,045	1,045	798	190	6	1	1
VIII	Wyoming							
	TOTAL	20,735	20,735	15,834	3,770	349	32	32
Region	I	1,155+	1,155+	882+	210+	10	1	1
	II	2,970	2,970	2,268	540	69	7	7
	III	1,815+	1,815+	1,386+	330+	35+	3+	3+
	IV	3,245+	3,245+	2,478+	590+	24+	3+	3+
	V	4,235	4,235	3,234	770	95+	9+	9+
	VI	1,045+	1,045+	798+	190+	19	2	2
	VII	(D)	(D)	(D)	(D)	13+	1+	1+
	VIII	(D)	(D)	(D)	(D)	(D)	(D)	(D)
	IX	1,705+	1,705+	1,302+	310+	57	5	(5)
	X	770	770	588	140			

Notes

(D) = Withheld to avoid disclosing figures for individual companies.

Source Foster D. Snell, Inc. compilations and analysis of waste streams reported during the industry survey.

TABLE II-40 (8)

		NEOPRENE			BUTYL RUBBER	
		Total Wastes	Potentially Hazardous Wastes	Flammable Chlorinated Hydrocarbons And Aromatic Still Bottoms (1)	Total Wastes	Potentially Hazardous Wastes (2)
IV	Alabama					
X	Alaska					
IX	Arizona					
VI	Arkansas					
IX	California					
VIII	Colorado					
I	Connecticut					
III	Delaware					
IV	Florida					
IV	Georgia					
IX	Hawaii					
X	Idaho					
V	Illinois					
V	Indiana					
VII	Iowa					
VII	Kansas					
IV	Kentucky	(D)	(D)	(D)		
VI	Louisiana	(D)	(D)	(D)	(D)	
I	Maine					
III	Maryland					
I	Massachusetts					
V	Michigan					
V	Minnesota					
IV	Mississippi					
VII	Missouri					
VIII	Montana					
VII	Nebraska					
IX	Nevada					
I	New Hampshire					
II	New Jersey					
VI	New Mexico					
II	New York					
IV	North Carolina					
VIII	North Dakota					
V	Ohio					
VI	Oklahoma					
X	Oregon					
III	Pennsylvania					
I	Rhode Island					
IV	South Carolina					
VIII	South Dakota					
IV	Tennessee					
VI	Texas	(D)	(D)	(D)	(D)	
VIII	Utah					
I	Vermont					
III	Virginia					
X	Washington					
III	West Virginia					
V	Wisconsin					
VIII	Wyoming					
	TOTAL	15,930	10,620	10,620	98	
	Region I					
	II					
	III					
	IV	(D)	(D)	(D)		
	V					
	VI	(D)	(D)	(D)	98	
	VII					
	VIII					
	IX					
	X					

Notes:
(D) = Withheld to avoid disclosing figures for individual companies.

(1) Concentrations not disclosed due to confidentiality

(2) No potentially hazardous wastes

TABLE II-40 (9)

		EPM-EPDM		COUMARONE-INDENE	
		Total Wastes	Potentially Hazardous Wastes(1)	Total Wastes	Potentially Hazardous Wastes
IV	Alabama			(D)	(D)
X	Alaska				
IX	Arizona				
VI	Arkansas				
IX	California			(D)	(D)
VIII	Colorado				
I	Connecticut				
III	Delaware				
IV	Florida				
IV	Georgia				
IX	Hawaii				
X	Idaho				
V	Illinois			(D)	(D)
V	Indiana				
VII	Iowa				
VII	Kansas				
IV	Kentucky				
VI	Louisiana	(D)		(D)	(D)
I	Maine				
III	Maryland				
I	Massachusetts			(D)	(D)
V	Michigan				
V	Minnesota				
IV	Mississippi			(D)	(D)
VII	Missouri				
VIII	Montana				
VII	Nebraska				
IX	Nevada				
I	New Hampshire				
II	New Jersey			(D)	(D)
VI	New Mexico				
II	New York				
IV	North Carolina				
VIII	North Dakota				
V	Ohio				
VI	Oklahoma				
X	Oregon				
III	Pennsylvania				
I	Rhode Island			1.116	1.116
IV	South Carolina				
VIII	South Dakota				
IV	Tennessee				
VI	Texas	(D)		(D)	(D)
VIII	Utah				
I	Vermont				
III	Virginia				
X	Washington				
III	West Virginia			(D)	(D)
V	Wisconsin				
VIII	Wyoming				
	TOTAL	33		5.328	5.328
	Region I			1.116+	1.116+
	II			(D)	(D)
	III			(D)	(D)
	IV			(D)	(D)
	V			(D)	(D)
	VI	33		(D)	(D)
	VII				
	VIII				
	IX			(D)	(D)
	X				

Notes

(D) = Withheld to avoid disclosing figures for individual companies.

(1) No potentially hazardous wastes

Source: Foster D. Snell, Inc. compilations and analysis of waste streams reported during the industry survey.

TABLE II- 41 (1)

ESTIMATED 1974 GEOGRAPHIC DISTRIBUTION
OF WASTES FOR THE SPINNING OPERATIONS
OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY --
SIC 282 (WET BASIS) (KKg/YEAR)

		NYLON 6		NYLON 6.6		POLYESTER	
		Total Wastes	Potentially (1) Hazardous Wastes	Total Wastes	Potentially (1) Hazardous Wastes	Total Wastes	Potentially (1) Hazardous Wastes
IV	Alabama	(D)		(D)		(D)	
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware	(D)		(D)		(D)	
IV	Florida	(D)		(D)			
IV	Georgia	(D)		(D)			
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa	(D)		(D)			
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland	(D)		(D)		(D)	
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York	(D)		(D)		(D)	
IV	North Carolina	(D)		(D)		(D)	
VIII	North Dakota						
V	Ohio					(D)	
VI	Oklahoma						
X	Oregon						
III	Pennsylvania	(D)		(D)		(D)	
I	Rhode Island						
IV	South Carolina	(D)		(D)		(D)	
VIII	South Dakota						
IV	Tennessee	(D)		(D)		(D)	
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	(D)		(D)		(D)	
X	Washington						
III	West Virginia	(D)		(D)		(D)	
V	Wisconsin						
VIII	Wyoming						
	TOTAL	116,850		16,132		708,400	
	Region I						
	II	(D)		(D)		(D)	
	III	40,125		5,537		31,350+	
	IV	76,375		10,540		299,750+	
	V					(D)	
	VI						
	VII	(D)		(D)			
	VIII						
	IX						
	X						

Note:
(D) = Withheld to avoid disclosing figures for individual companies.
(1) No potentially hazardous wastes

Source: Foster D. Snell, Inc. compilations and analysis of waste streams reported during the industry survey.

TABLE II-41 (2)

		ACRYLICS		CELLULOSE ACETATE		RAYON	
		Total Wastes	Potentially Hazardous Wastes	Total Wastes	Potentially (1) Hazardous Wastes	Total Wastes	Potentially Hazardous Wastes
IV	Alabama	(D)	(D)			(D)	
X	Alaska						
IX	Arizona						
VI	Arkansas						
IX	California						
VIII	Colorado						
I	Connecticut						
III	Delaware						
IV	Florida	(D)	(D)				
IV	Georgia			(D)			
IX	Hawaii						
X	Idaho						
V	Illinois						
V	Indiana						
VII	Iowa						
VII	Kansas						
IV	Kentucky						
VI	Louisiana						
I	Maine						
III	Maryland			(D)			
I	Massachusetts						
V	Michigan						
V	Minnesota						
IV	Mississippi						
VII	Missouri						
VIII	Montana						
VII	Nebraska						
IX	Nevada						
I	New Hampshire						
II	New Jersey						
VI	New Mexico						
II	New York						
IV	North Carolina						
VIII	North Dakota						
V	Ohio						
VI	Oklahoma						
X	Oregon						
III	Pennsylvania			(D)			
I	Rhode Island						
IV	South Carolina	(D)	(D)	(D)			
VIII	South Dakota						
IV	Tennessee	(D)	(D)	(D)		(D)	(D)
VI	Texas						
VIII	Utah						
I	Vermont						
III	Virginia	(D)	(D)	(D)			
X	Washington						
III	West Virginia					(D)	(D)
V	Wisconsin						
VIII	Wyoming						
	TOTAL	347.500	278.000	330		5.660	5.660
Region	I						
	II						
	III	(D)	(D)	184		(D)	(D)
	IV	(D)	(D)	146		(D)	(D)
	V						
	VI						
	VII						
	VIII						
	IX						
	X						

Note:

(D) = Withheld to avoid disclosing figures for individual companies.

(1) No potentially hazardous wastes

Source: Foster D. Snell, Inc., compilations and analysis of waste streams reported during the industry survey.

TABLE II-42

TOTAL ESTIMATED WASTES FOR THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY -- SIC 282
(WET BASIS) (KKg/YEAR)

		1974(1)		1977(2)		1983(2)	
		Total Wastes	Potentially Hazardous Wastes	Total Wastes	Potentially Hazardous Wastes	Total Wastes	Potentially Hazardous Wastes
IV	Alabama	385+	385+	466+	466+	601+	601+
X	Alaska						
IX	Arizona						
VI	Arkansas	(D)	(D)	(D)	(D)	(D)	(D)
IX	California	42,704+	38,510+	51,672+	47,807+	66,618+	61,636+
VIII	Colorado	(D)	(D)	(D)	(D)	(D)	(D)
I	Connecticut	1,050+	252+	1,271+	305+		383+
III	Delaware	(D)	(D)	(D)	(D)	(D)	(D)
IV	Florida	1,589+	1+	1,923+	1+	2,479+	2+
IV	Georgia	391+	386+	473+	467+	610+	602+
IX	Hawaii						
X	Idaho	4,116	3,430	4,980	4,150	6,421	5,351
V	Illinois	1,433+	1,269+	1,734+	1,535+	2,235+	1,980+
V	Indiana	8+	1+	10+	1+	12+	2+
VII	Iowa	(D)	(D)	(D)	(D)	(D)	(D)
VII	Kansas	(D)	(D)	(D)	(D)	(D)	(D)
IV	Kentucky	10+	1+	12+	1+	16+	2+
VI	Louisiana	24,779+	2,679+	29,983+	3,241+	38,665+	4,179
I	Maine	(D)	(D)				
III	Maryland	10+	1+	12+	1+	16+	2+
I	Massachusetts	10,377+	4,036+	12,556+	4,883+	16,188+	6,296+
V	Michigan	1,420+	386+	1,718+	467+	2,215+	602+
V	Minnesota	(D)	(D)	(D)	(D)	(D)	(D)
IV	Mississippi	(D)	(D)	(D)	(D)	(D)	(D)
VII	Missouri	757+	1+	916+	1+	8,181+	2+
VIII	Montana	(D)	(D)	(D)	(D)	(D)	(D)
VII	Nebraska						
IX	Nevada						
I	New Hampshire	(D)	(D)	(D)	(D)	(D)	(D)
II	New Jersey	42,218+	34,115+	51,084+	41,279+	65,060+	[illegible]
VI	New Mexico						
II	New York	65,726+	65,462+	79,528+	79,209+	102,533+	102,121+
IV	North Carolina	43,548+	10,415+	52,693+	12,602+	67,935+	16,247+
VIII	North Dakota						
V	Ohio	88,688+	81,684+	119,412+	98,838+	153,953+	127,427+
VI	Oklahoma	(D)		(D)		(D)	
X	Oregon	25,571+	25,540+	30,941+	30,903+	38,881+	38,842+
III	Pennsylvania	5,420+	1,432+	6,558+	1,732+	8,455+	2,234+
I	Rhode Island	1,896+	1,896+	2,415+	2,415+	3,114+	3,114+
IV	South Carolina	34,250+	860+	41,443+	799+	53,430+	1,030+
VIII	South Dakota						
IV	Tennessee	26,198+	(D)	31,699+	(D)	40,862+	(D)
VI	Texas	81,787+	42,807+	111,062+	51,796+	153,188+	66,779+
VIII	Utah	(D)	(D)	(D)	(D)	(D)	(D)
I	Vermont						
III	Virginia	2,713+	385+	3,283	466+	4,232	601+
X	Washington	770+	770+	932+	932+	1,201+	1,201+
III	West Virginia	3,317+	770+	4,013+	(D)	5,175+	(D)
V	Wisconsin	1,051+	1,046+	1,272+	1,266+	1,639+	
VIII	Wyoming						
	TOTAL	1,829,987	730,021	2,335,284	883,325	3,010,780	1,138,833
	Region I	13,423+	5,168+	16,242+	6,253+	20,940+	8,062
	II	107,575+	100,693+	130,166+	121,839+	167,817+	157,081+
	III	65,311+	1,818+	103,226+	2,200+	133,085+	2,836+
	IV	577,176+	16,788+	698,383+	20,313+	900,395+	26,189
	V	93,361+	85,386+	112,967+	103,317+	145,643+	54,735+
	VI	108,298+	40,546+	131,041+	49,061	168,945+	63,252+
	VII	757+	1+	916+	1+	1,181+	2+
	VIII	(D)	(D)	(D)	(D)	(D)	(D)
	IX	42,704+	39,510+	51,672+	47,807+	66,618+	61,636+
	X	28,907+	28,600?	34,977+	34,605+	45,095+	44,616+

Notes:

+ indicates that waste values for state and regions interchange more than the weight indicated. Absolute volumes could not be repeated due to disclosure problems.

(D) Values not given due to possibility of disclosure

(1) Based on Tables II-

(2) Based on weighted average growth in SIC 2821, 2822, 2823 and 2824 for these years as estimated from INFORM input/output model use.

The basic factors influencing the evaluation of solid waste volume for 1977 and 1983 are:

- Production volume changes
- The effect of more stringent requirements of water pollution control.

The waste loads for 1977 are expected to vary only with changes in production output. The effect of the 1977 Water Effluent Guidelines Regulations is not expected to be significant because, as most of the plant personnel interviewed indicated, the technology necessary to meet the 1977 requirements is already in place. Thus, the waste factors developed in this study already account for this technology.

For 1983, the cumulative effect of uncertainties in changes of production volume and water regulations is such that the only feasible approach to making the projections, at present, appears to be to discount elements other than production growth. This situation results because the analysis of non-water impacts of the 1983 Water Effluent Guidelines (as presented in the Development Documents for the relevant industries), does not appear to provide the information necessary to evaluate realistically the changes in waste factors per unit production. The procedure followed for the 1983 projections is, therefore, based on changes in production volume only.

Estimates of production for the years 1977 and 1983 were obtained from the Interindustry Economic Research Project of the University of Maryland (INFORUM) input/output model of the U.S. economy. The model analyzes the economy into 200 industrial sectors generally corresponding with the four-digit 1967 Standard Industrial Classifications. The model, its inputs and assumptions are discussed in Appendix A.

Table II-43 presents production in terms of producer prices (1972 dollars) for the years 1974, 1977 and 1983 for each of the four-digit SICs comprising SIC 282.

TABLE II - 43

PRODUCT SHIPMENTS IN PRODUCER PRICES FOR THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY -- SIC 282

		Product Shipments in Producer Prices (Millions of 1974 Dollars)				
SIC	Industry	1974	1977	% Change Over 1974	1983	% Change Over 1974
2821	Plastic Resins	6,266	8,013	+28%	11,454	+83%
2822	Synthetic Rubber	1,345	1,489	+11%	1,605	+19%
2823	Cellulosic Manmade Fibers	681	840	+23%	933	+37%
2824	Manmade Fibers, Non-Cellulosic	3,454	4,099	+19%	5,094	+48%
282	Plastic Materials and Synthetics			+21%(1)		+56%(1)

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(1) Weighted average growth rate developed from 1974 production volume breakdown of SIC 2821, 2822, 2823 and 2824 as presented in Tables II-12, II-14, II-26 and II-28. For example, the contribution of SIC 2821, 2822, 2823 and 2824 to total SIC production volume for 1974 are 38%, 17%, 2% and 43%, respectively. Thus, SIC 282 weighted average growth rate for 1977 is: (38% of 28%) + (17% of 11%) + (2% of 23%) + (43% of 19%) = 21%.

Source: INFORUM Input/Output Model, University of Maryland, June, 1975.

A weighted average growth rate for the entire SIC 282 was developed based on 1974 production volume breakdown of SIC 2821, 2822, 2823 and 2824. This growth rate for the years 1977 and 1983 are projected to be:

Table II-44 -- Projected Average Growth Rate Over 1974

	1977	1983
SIC 282	21%	56%

Source: Table II-42

These growth rate factors were multiplied by the estimated 1974 wastes to project the 1977 and 1983 loads.

Total wastes for the years of interest are estimated as follows:

Table II-45 -- Estimated Total Wastes For 1974, 1977 and 1983 (KKg/yr.)

	Wet Basis	Dry Basis
1974	2,751,319	1,504,469
1977	3,329,095	1,820,407
1983	4,294,533	2,348,326

Based on an estimated industry wide total, 1974 production of 30,472 KKKg, total wastes amount to 6% of production volume on a weight basis.

4.4.2 Potentially Hazardous Wastes

Potentially hazardous waste quantities for 1974 by product are presented in Table II-40 and II-41. Table II-42 presents total potentially hazardous wastes for the entire SIC 282 for the years 1974, 1977 and 1983.

The information presented in these tables was arrived at in a manner similar to that used for total wastes, as discussed in Section 4.4.1. The values were developed by taking the starred (*) waste factors (those considered to be potentially hazardous) from Tables II-46 and II-47 for each product and multiplying them by their respective production from Tables II-8, II-11, II-32 and II-34. Tables II-40 and II-41 were then totaled to produce the potentially hazardous waste values in Table II-42 for 1974. The values for 1977 and 1983 were developed using the average weighted growth factors as per Section 4.4.1.

From Table II-42, potentially hazardous wastes for the years of interest are summarized as follows:

Table II-48 -- Estimated Potentially Hazardous Wastes For 1974, 1977 and 1983 (KKg/Yr.)

	Wet Basis	Dry Basis
1974	740,351	157,347
1977	895,824	190,389
1983	1,155,614	245,602

Within SIC 282, the largest contributors to the potentially hazardous land destined wastes are:

- Polystyrene
- Phenolics
- Amino resins
- Acrylics (spinning processes).

The largest single contributor is phenolics with an estimated 366,000 KKg in 1974 of an aqueous solution of phenol and formaldehyde as the potentially hazardous constituent.

TABLE II-46 (1)

COMPILATION OF THE REPORTED WASTE FACTORS IN THE POLYMERIZATION OPERATIONS IN THE MANUFACTURE OF PLASTICS AND MANMADE FIBERS -- SIC 282

Rank	Product[1]	Class[2]	Production KKKg/Yr.	Type	Waste Streams[3] (Kg/KKg of Product)		
					Off-Grade Products	Still Bottoms And Waste Oils	Other
1	Polyester	F	6,855	Polyester	30	0.1	Terephthalic Acid 1.0
2	Polyamides	F	4,727	Nylon 6,6	3.0		Spent filter and cake 0.06 Waste water sludge 3.5
				Nylon 6	2		
3	Polyethylene	O	4,018	Low Density	10	1	
				High Density	3.0	0.5	Spend adsorbent 0.006 Spent catalyst[4] 0.037
4	Vinyl Resins	O	2,277	PVC (Emulsion)	20		Wastewater sludge 11
				PVAc (Latex)	10	1.0	
5	Styrene Butadiene Rubber	O	2,216	Emulsion	15	1.5	Wastewater sludge 3
				Solution	10	10	Wastewater sludge 10
6	Styrene Resin	O	2,244	Polystyrene	2.0	10	
				ABS-SAN	20	5.0	Wastewater sludge 11
7	Polypropylene	O	2,196	Polypropylene	5.0	10	Wastewater sludge (dry) 2 Nitrile waste 0.5
8	Acrylics	F	2,117	Acrylics	2.0	7	
9	Phenolics	R	610	Phenolics	8	500 (5)	Wastewater sludge 60
10	Polyurethanes	R	538	Prepolymer	N.A.	250(6)	

TABLE II-46 (2)

Rank	Product(1)	Class(2)	Production KKKg/Yr.	Type	Waste Streams(3) (Kg/KKg of Product) Off-Grade Products	Still Bottoms And Waste Oils	Other
11	Polybutadiene	O	477	Polybutadiene	2	0.1*	Spend adsorbent 0.1
12	Amino Resin	R	377	Urea Formaldehyde	10*	42*	Filter Cake 2.4*
13	Alkyds	R	317	Alkyds	1		Sweepings 0.1*
14	Neoprene	O	177	Neoprene	30	60*	
15	Butyl Rubber	O	166	Butyl Rubber	None reported(7)	None reported(8)	Spent Adsorbent 0.6
16	EPM-EPDM	O	163	EPM-EPDM	None reported(7)	None reported(8)	Spent adsorbent 0.6 Spent catalyst 0.2 (8)
17	Coumarone-Indene	R	148	Coumarone-Indene	None reported(7)	None reported(9)	Spent clay 36*(10)
18	Epoxy	R	143(6)	Epoxy			
19	Silicone	R		Gum	90	30	Spent adsorbent 5
				Rubber(11)	With "other"	40	Scrap 30
				Total(12)	54	58	33

---

(1) Products are ranked in order of decreasing production tonnage.

(2) Foster D. Snell, Inc. classification symbol for polymer groups: O = Olefinic; F = Non-olefinic, mainly used in fiber production; R = Non-olefinic, mainly used as resin.

(3) The classes are self-evident or defined in the text.

(4) This is only for the product made by the Phillips process

(5) Essentially a water stream containing about 7.5% soluble organic materials (phenol).

(6) Essentially a water stream containing about 5.0% soluble organic materials.

(7) Off-grade material sold for special use.

(8) Solvent recovered at production sites.

(9) The process is such that discarded stream has characteristics of #2 fuel oil.

(10) This figure is for the resin produced by one of several solution processes only and should not be generalized to the total production.

(11) These wastes are in addition to those reported for the gum, the bulk of which goes to rubber production and constitutes about 60% of the finished rubber.

(12) The figures reflect the fact that only 60% of the figures for gums are additive to those for rubber.

* These streams are designated potentially hazardous.

Source: Foster D. Snell, Inc. analysis of industry interviews and literature information.

TABLE II-47

COMPILATION OF THE REPORTED WASTE FACTORS IN THE SPINNING OPERATIONS IN THE MANUFACTURE OF MANMADE FIBERS -- SICs 2823 and 2824

		Waste Streams (Kg/KKg of Product)			
Product	**Method**	**Off-Grade Product**	**Waste Water Sludges**	**Finishing Oils**	**Other**
Polyester	Melt	40	None reported	70 [(1)]	Sand Filter 0.2
Polyamides					
Nylon 6	Melt	40	None reported	None reported	Polymer 10
Nylon 6,6	Melt	4.5	None reported	1.7	Lube oil 0.7
Acrylics	Wet	50	200* [(2)]	Not individually reported	
Cellulose Acetate	Dry Spinning	2	None reported	None reported	
Rayon	Wet		200*		

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(1) Essentially a water dispersion containing 7% to 10% organic material.
(2) This represents a sludge production typical of a salt solution process.

* These streams are designated potentially hazardous.

Source: Foster D. Snell, Inc. analysis of industry interviews and literature information.

5. TREATMENT AND DISPOSAL TECHNOLOGY FOR POTENTIALLY HAZARDOUS WASTES IN THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282

In the preceding section the potentially hazardous waste streams generated by SIC 282 have been described and quantified. In this section these streams are correlated to the specific disposal methods used and the adequacy of these methods assessed in the light of three levels of technology defined below.

- Level I -- Technology Currently Employed By Typical Facilities. This level represents the broad average treatment and disposal practice.

- Level II -- Best Technology Currently Employed. This level represents the best practice from an environmental and health standpoint, currently in use in at least one location. Installations must be commercial scale. Pilot and bench scale installations are not suitable.

- Level III -- Technology Necessary To Provide Adequate Health And Environmental Protection. Level III technology may be more or less sophisticated or may be identical with Level I or II technology. At this level, identified technology may include pilot or bench scale processes providing the exact stage of development is identified.

The disposal methods presently encountered in this industry are:

- Incineration
- Landfill
- Lagooning
- Storage

It should be noted that contract disposal ultimately results in the use of one of the above methods.

The discussion of the treatment and disposal methods applicable to the potentially hazardous waste streams in SIC 282 differs somewhat from that presented in the following chapter for SIC 30 industry. The reasons are considerable differences:

- in production technologies

- in nature of waste streams

- in disposal technology

- in degree of development of potential technologies.

In the subsequent sections the broad categories of applicable disposal technologies are presented, followed by a detailed discussion of treatment and disposal technology by types of hazardous waste.

5.1 Treatment And Disposal In SIC 282

The following paragraphs discuss treatment and disposal technologies applicable to the Plastic Materials and Synthetics Industry. In some instances restrictions on the permissibility of alternative disposal methods may shift the disposal of certain streams in the direction of recovery. For instance, the additional expense of meeting adequate standards in disposal method X, currently practiced, added to the presently insufficient value of the recovered product, may make recovery economically attractive.

In many instances, however, indefinite recovery and reuse may not be feasible due to accumulation of undesirable impurities. In this case, a portion of the wastes is disposed of through other methods. This appears to be the case for the disposal of zinc oxides to landfill at certain plants of SIC 282.

5.1.2. Controlled Incineration

This method is universally practiced in the SIC 282 industries. Indeed, the fact that a waste is incinerated may be taken as prima-facie evidence of the undesirability of disposing of it by other methods. However, it is not always the case. For example, incineration may be more economical than landfilling because of considerations of volume, transportation costs or value of the waste as a fuel. An extreme case is that of the coumarone-indene industry in which some waste streams are indistinguishable from #2 fuel oil. At present, state regulations are such that monitoring and control are the rule on all incineration equipment. Installations still lacking in these features are scheduled to be equipped or replaced to meet the standards. Incineration can be performed on-site or contracted out. The only reason for contracting out is economics and thus contracting out does not represent a technological alternative.

5.1.3. Open Dumping

The majority of industry firms contacted have become increasingly aware of their responsibility for the proper treatment and disposal of their wastes. They have related, during the course of the interviews, that they are taking an active role in investigating what is occuring at their own sites as well as those of private contractors.

5.1.4. Burial Operations And Landfills

These represent the other major disposal technology used in SIC 282 for those wastes which are classified as potentially hazardous and which are not incinerated. These wastes are essentially wastewater treatment sludges contaminated by metal ions. When inadequate landfill sites are still in use, measures are universally being taken to improve the situation by resorting to secure landfill. Since this technology is more universally used for SIC 30 and to avoid repetition, the detailed discussion of these operations is in Chapter III, Section 7.3.

5.1.5. Ponding And Lagooning

This represents a technology widely used in the production sites of SIC 282, particularly on the Gulf Coast. However, no significant amount of potentially hazardous wastes originating in SIC 282 operations appear to be disposed of by this technique.

This technique provides a simple and economic approach to on-site potentially hazardous waste disposal, where applicable. However, there are some significant drawbacks.

- The pond must provide protection from both surface and groundwater contamination. In almost all areas, this requires a liner. Liners include clay, plastic, concrete, and epoxy, all of which are relatively expensive.

- Except in very dry climates, ponds without discharge will overflow from rainfall accumulation.

- Ponds are prone to be "flushed out" with massive rainfall. It is difficult and expensive to provide flood protection.

The type of production carried out at most of the sites is such that it is impossible to evaluate precisely the contribution to the utilization of these facilities by processes involving SIC 282 products. At most, 5% to 10% of the streams collected in such facilities come directly from SIC 282 operations, and in no case have these been considered potentially hazardous.

5.2 Treatment And Disposal In SIC 282 By Hazardous Waste Type

It is evident from the discussion in the previous sections that the segmentation of SIC 282 into the Department of Commerce segments does not provide a sound framework for the technical discussions associated with products and processes. In particular, the distinction between SIC 2821, Plastics, and SIC 2822, Synthetic Rubber, is inapplicable since the same name processes (e.g., Ziegler or Phillips) are used for some products in both segments.

5.2.1 Treatment And Disposal Of Potentially Hazardous Wastes Generated In Phenolics Production

The phenolic resins constitute the one group in which a substantial potentially hazardous waste problem exists for the following reasons:

- Substantial production (610 KKKg/yr)
- Large volume of potentially hazardous wastes (50% by weight)
- Inadequate present long range disposal methods.

For treatment and disposal the potentially hazardous wastes generated in the manufacture of phenolic resins are separated into two streams:

- A liquid stream of low viscosity, containing organics including phenols and/or formaldehyde easily pumpable with varying degrees of turbidity
- A solid/semi-solid of varying consistency which contains oligomers and excess phenol and which is difficult, if not impossible, to pump by conventional means.

At present the practice is to incinerate the liquid stream and to store the solid/semi-solid stream in ponds or lagoons until a satisfactory disposal method has been developed.

A problem associated with the incineration of the liquid stream is that it does not contain enough organic material to sustain its own combustion. At one of the sites visited, a backlog of waste solvents of various origins (mostly outside the scope of SIC 282 operations) has permitted the incineration of this stream without use of purchased fuel for the past several years. However, this practice is not generally feasible. It appears that the stream to be incinerated does not bring elements requiring further treatment of the combustion gases. At the other plants, this material is generally stored on-site in drums.

Obviously, even though the precautions to prevent dispersion into the environment of the solid/semi-solid stream are presently satisfactory, storage is not an environmentally adequate solution in the long run. The viscosity of this material prevents its disposal by incineration, at least in the incinerator configurations commercially available today. Disposal methods are reportedly under investigation. But due to their specialized nature and the disproportionate costs of development, these methods are kept strictly proprietary.

5.2.2. Potentially Hazardous Waste Constituted By Partly Unreacted Amino Resins

Equipment upsets or human error are responsible for the wastes destined for land disposal and the need to dispose of relatively small amounts of partly unreacted mixtures of urea or melamine and formaldehyde. The material is drawn off from the reactor, drummed in sealed drums and adequately incinerated under contract by a professional waste treatment firm. This, provided that the treatment firm is aware of the potential hazard to the immediate personnel, appears to constitute an environmentally adequate disposal method. If local incineration facilities exist, there is no reason not to dispose of this material via that route.

5.2.3. Potentially Hazardous Waste Created By The Handling Of Catalyst In Polyester Production

A waste stream consisting of a mixture of manganese salts and antimony compounds has been reported by polyester manufacturers. Proprietary considerations have prevented further inquiry into the extent of this stream. Literature confirms the use of salts of manganese, cobalt and cadmium as catalysts in polyester production. At present the material is stored in drums until development of a more suitable disposal method occurs. However, technology for adequate disposal would appear to be disposal in a secured landfill.

5.2.4 Still Bottoms As Potentially Hazardous Wastes

Whatever their composition, the universal practice in the industry is to dispose of still bottoms in two ways:

- If the product has a merchant value -- e.g., amorphous polypropylene or other oligomers-- it is sold as a by-product.
- If the product has no merchant value, it is disposed of by oxidation.
  - Biological if biodegradable
  - Incineration if combustible.

Special consideration is made here of certain still bottoms which are felt to be highly flammable and/or to contain hazardous (possibly carcinogenic) compounds. These are invariably incinerated. The sophistication of the plant involved is such that in most cases the best available equipment is used. Generally, the load imposed on the establishment's incinerator by the subject wastes is insignificant compared to the requirements of other production facilities at the same location. In some instances, recovery of heat value was a plus, economically and ecologically.

It must be noted that, inasmuch as the practice of controlled incineration, either on-site or by contractor, is universal and most of the non-aqueous still bottoms are essentially ash free, the bulk of this stream can be considered presently handled with environmentally adequate technology regardless of whether it is otherwise potentially hazardous or not. The problem of the chlorinated solvents is presently handled through scrubbing of the off-gases and some recovery of the HCl generated.

The net result of biological oxidation of aqueous still bottoms containing dissolved biodegradable organics is a small production of biological sludge. It is usually impossible to quantitatively connect this sludge formation with the production volume. Industrial biological sludges produced from still bottoms in polymer production are insignificant at the sites where there is this type of water treatment.

5.2.5. Potentially Hazardous Wastes From Cellulosic Production

Of all the processes in this group, rayon production is one of the most likely to generate potentially hazardous wastes. Here the situation parallels somewhat that which is encountered in the reclaimed rubber industry which is discussed in the following chapter; that is, at present this industry is undergoing rapid changes. Several interviewees indicated that they had suspended production or even abandoned production at many of their facilities. As noted before, economic conditions were mentioned as the reason for the shutdowns.

The main waste problem associated with rayon production is a waste stream containing large amounts of zinc salts. The common practice is to adjust the pH of the stream, to precipitate the zinc and separate the precipitate by filtration or centrifugation. The zinc cake (zinc oxide or hydroxide) can then be disposed of in one of three ways:

- Recovery and reuse in the plant
- Sale for recovery off-site
- Burial in secured landfill.

Economic and local conditions usually dictate the ultimate disposal of this zinc cake (1). In at least one plant a very thorough study of the economics was internally performed and the local conditions were such that the development of a secured landfill site was found to be the most economical. However, conditions vary and the disposal methods at other locations may be different. It is also reported that the quantity of zinc thus produced varies considerably depending on the type of product and operating conditions.

5.2.6. Potentially Hazardous Wastes In Acrylic And Modacrylic Spinning

One of the spinning methods for acrylic and modacrylic fibers involves dissolution of the fibers in a concentrated solution of metallic salts, usually zinc chloride. The plants are usually equipped to recover this stream. However, variable quantities resulting from production up-sets have to be discarded, usually in the form of oxides. The disposal method for this stream is secured landfill.

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(1) That is, if the market price of zinc is high enough it will be recovered.

5.2.7 Potentially Hazardous Waste Solvents In Silicone Production

The industry structure is such that, to preserve confidentiality, little can be said about this stream except that it is disposed of by incineration. Since the operations investigated are carried out in states with strong antipollution regulations, it is assumed that incineration is carried out in an environmentally adequate controlled manner.

5.3. Treatment And Disposal Technology Levels As Applied To Potentially Hazardous Wastes Produced By The Plastic Materials And Synthetics Industry, SIC 282

The levels of treatment and disposal technology have been characterized in the opening paragraph of Section 5. The following factors have been employed in evaluating the technologies used or to be developed by the industry for the treatment and disposal of potentially hazardous wastes.

- Factor I -- Physical And Chemical Properties Of The Waste. This gives a brief description of the form of this waste and identifies the main constituents
- Factor II -- Amount Of Waste (Kg/KKKg Of Product). This factor gives an average quantity or range of the magnitude of the total potentially hazardous waste streams treated based upon a waste factor relating the quantity of waste (kilograms) to the quantity of production.
- Factor III -- Factors Affecting Degree of Hazard From The Waste. This gives a brief description of the possible interaction of the surrounding environment with the waste.
- Factor IV -- Adequacy Of Technology. A description of the technology with respect to environmental considerations and load regulations in terms of present and future conditions.
- Factor V -- Non-Land Environmental Impact. This describes the possible impact of the technology on non-land environmental factors such as water or air quality.
- Factor VI -- Problem Areas Or Comments. A brief description of problem areas encountered with the technology or important comments.
- Factor VII -- Compatibility With Existing Facilities. This evaluation factor describes whether the technology can be used by existing plants or waste disposal contractors.

- Factor VIII -- Monitoring And Surveillance Techniques. This describes the type and frequency of monitoring necessary for the technology.

- Factor IX -- Installation Time For New Facility. This factor provides information on whether or not the treatment and disposal technology has been installed or how long it will take to get it on-stream.

- Factor X -- Energy Requirements. This factor describes the qualitative amount of energy required for the technology.

With the exception of two streams, for which no adequate technology has yet been developed, the treatment and disposal practices of the SIC 282 consist of:

- Secured landfill
- Incineration(1)
- Recovery.

The treatment and disposal technologies of the potentially hazardous waste streams discussed in Section 5.2 are applied to the three treatment and disposal technologies in a series of tables.

- Table II-49, Liquid Phenolic Wastes
- Table II-50, Solid/Semi-solid Phenolic Wastes
- Table II-51, Off-Grade Product From Amino Resin Production
- Table II-52, Waste Catalyst Stream From Polyester Production
- Table II-53, Still Bottoms (Aromatic, Aliphatic, Chlorinated, Etc.) From All SIC 282 Processes Producing Such Waste Streams
- Table II-54, Zinc Oxide Sludges From Wastewater Treatment In Cellulosic And Acrylic Fiber Production

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(1) Previous studies in this group identified two levels of incineration, so-called uncontrolled and controlled. Air pollution abatement regulations have been instituted in most states, so that incineration as practiced in 1975 is controlled.

TABLE II-49

TREATMENT AND DISPOSAL TECHNOLOGIES FOR LIQUID PHENOLIC WASTES -- SIC 2821

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health And Environmental Protection
Physical and Chemical Properties of Residual Wastes	Water solutions of various organic species, including phenols and/or formaldehyde	Same as Level I	Same as Level II
Amount of Residual Wastes (Kg/KKKg Product)	500	Same as Level I	
Factors Affecting Hazardousness	Phenols and formaldehyde are toxic to human, animal and plant life	Same as Level I	
Treatment/Disposal Technology	Drum storage	Controlled Incinerator	
Estimate of Number or Percent of Plants Now Using Technology	50%	50%	
Adequacy of Technology	Inadequate	Adequate if air pollution control is pratical	
Non-Land Environmental Impact	None, if drums remain sealed	Same as Level I	
Problems and Comments	Potential for drums to corrode and spill contents	Necessity to "burn" large amounts of water, excessive costs and fuel consumption	
Compatibility with Existing ing Facilities	Compatible	Same as Level I	
Monitoring and Surveillance Techniques	Periodic inspection of drums to insure they are not leaking	Air monitoring	
Installation Time for New Facility	N.A.	1 Year	
Energy Requirements	None	600 K Cal/Kg(1,100 BUT/lb.)	

Source: Foster D. Snell, Inc., analysis of company interviews.

TABLE II-50

TREATMENT AND DISPOSAL TECHNOLOGIES FOR
SOLID/SEMI-SOLD PHENOLIC WASTE

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health And Environmental Protection
Physical and Chemical Properties of Residual Wastes	Putty-like substances with phenolic odors. Oligomers and excess phenol	Same as Level I	Same as Level I
Amount of Residual Wastes (Kg/KKKg Product)	68		
Factors Affecting Hazardousness	Toxicity resulting from the presence of phenols		
Treatment/Disposal Technology	Storage in drums or concrete lined lagoons		
Estimate of Number or Percent of Plants Now Using Technology	100%	100%	
Adequacy of Technology	Inadequate	Same as Level I	No method is presently available
Non-Land Environmental Impact	Odor problems		
Problems and Comments	Limited storage space, leaching into ground or surface water		Same as Level I
Compatibility with Existing Facilities	Compatible		
Monitoring and Surveillance Techniques	None		
Installation Time for New Facility	Short		
Energy Requirements	None		

Source: Foster D. Snell, Inc., analysis of company interviews.

TABLE II-51

TREATMENT AND DISPOSAL TECHNOLOGIES FOR STILL BOTTOMS (AROMATICS, ALIPHATICS, CHLORINATED, ETC.)[1] IN ALL SIC 282 PRODUCING SUCH WASTE STREAMS

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health And Environmental Protection
Physical and Chemical Properties of Residual Wastes	Viscous liquids, hydrocarbons (aromatics, chlorinated) (ash free)	Same as Level I	Same as Level I
Amount of Residual Wastes (Kg/KKKg Product)	Varying with the individual product stream	Same as Level I	Same as Level I
Factors Affecting Hazardousness	Flammable solvents -- human, animal and plant life toxicity (carcinogenicity)	Same as Level I	Same as Level I
Treatment/Disposal Technology	Controlled incineration	Same as Level I	Present Technology
Estimate of Number or Percent of Plants Now Using Technology	100% (see "Compatibility")	100%	100%
Adequacy of Technology	Adequate	Adequate	Adequate
Non-Land Environmental Impact	None, if incineration is controlled	None, if incineration is controlled	None, if incineration is controlled
Problems and Comments	None, in well designed and maintained equipment	Same as Level I	Same as Level I
Compatibility with Existing Facilities	Certain operations are on too small a scale to justify installation of facilities. Contract incineration is preferred		
Monitoring and Surveillance Techniques	Automatic flame control. Stack gas analysis		
Installation Time for New Facility	6 mo. - 1 year on-site depending on size		
Energy Requirements	In general self-sustaining. Sometimes minimal amount of auxiliary fuel		

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[1] The facilities are universally used indiscriminately and simultaneously for hazardous and non-hazardous wastes and are perfectly adequate for either. The so-called "potentially hazardous" wastes of SIC 282 disposed of by incineration do not require control technology in the incinerators. This technology is, however, generally incorporated since the burners are also used for other products.

Source: Foster D. Snell, Inc., analysis of company interviews.

TABLE II-52

TREATMENT AND DISPOSAL TECHNOLOGIES FOR OFF-GRADE PRODUCT IN AMINO RESIN PRODUCTION -- SIC 2821

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health And Environmental Protection
Physical and Chemical Properties of Residual Wastes	Semi-solid to solid material containing excess formaldehyde	Same as Level I	Same as Level I
Amount of Residual Wastes (Kg/KKKg Product)	10	Same as Level I	Same as Level I
Factors Affecting Hazardousness	Formaldehyde fumes	Same as Level I	Same as Level I
Treatment/Disposal Technology	Drumming at site followed by contract incineration by controlled equipment	See footnote (1)	See footnote (1)
Estimate of Number or Percent of Plants Now Using Technology	100%	Same as Level I	Same as Level I
Adequacy of Technology	Adequate		
Non-Land Environmental Impact	None		
Problems and Comments	See footnote(1)		
Compatibility with Existing Facilities	See footnote(1)		
Monitoring and Surveillance Techniques	As required by local ordinances		
Installation Time for New Facility	N.A.		
Energy Requirements	Negligible		

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(1) Basically, all such streams can be incinerated. Disposal by contract incineration is subject to the same conditions of volume considerations. Conceivably some production sites may have local incineration, usually by reason of other production. Such situation cannot be construed as Level II, because contract incineration is, by definition, environmentally adequate.

N.A. = Not Applicable

Source: Foster D. Snell, Inc., analysis of company interviews.

TABLE II- 53

TREATMENT AND DISPOSAL TECHNOLOGIES FOR
WASTE CATALYST STREAM IN POLYESTER PRODUCTION
-- SIC 282

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health And Environmental Protection
Physical and Chemical Properties of Residual Wastes	Solid mixture of mineral salts, crystals and powders (proprietary)	Same as Level I	Same as Level I
Amount of Residual Wastes (Kg/KKKg Product)	Negligible(1)		Same as Level I
Factors Affecting Hazardousness	High toxicity and solubility of catalyst		Same as Level I
Treatment/Disposal Technology	Storage in drums		Adequate technology unavailable at present
Estimate of Number or Percent of Plants Now Using Technology	100%		
Adequacy of Technology	Inadequate		
Non-Land Environmental Impact	Potential leaching of water into ground or surface waters		
Problems and Comments	Bothersome stream, too small to warrant development of a technology; too large to ignore		
Compatibility with Existing Facilities	N.A.		
Monitoring and Surveillance Techniques	Periodic inspection of containers		
Installation Time for New Facility	N.A.		
Energy Requirements	N.A.		

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(1) Inclusion of this stream in this study is due to the high toxicity of the materials involved and the reported present lack of disposal technology. The total amounts represent at most a few dozens of 55 gallon drums at major production locations.

N.A. = Not Applicable

Source: Foster D. Snell, Inc., analysis of company interviews.

TABLE II-54

TREATMENT AND DISPOSAL TECHNOLOGIES FOR ZINC OXIDE SLUDGES FROM WASTEWATER TREATMENT IN CELLULOSIC AND ACRYLIC FIBER PRODUCTION

-- SIC 2824

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health And Environmental Protection
Physical and Chemical Properties of Residual Wastes	Watery solids and semi-solids containing large amounts of zinc oxide	Same as Level I	Same as Level II
Amount of Residual Wastes (Kg/KKKg Product)	Variable depending on operating conditions	Same as Level I	
Factors Affecting Hazardousness	Potential leaching of zinc ion into ground and surface	Same as Level I	
Treatment/Disposal Technology	Secured landfill	Recovery (2)	
Estimate of Number or Percent of Plants Now Using Technology	Variable, depends on economics	Variable depends on economics	
Adequacy of Technology	Adequate if landfill is secured	Adequate	
Non-Land Environmental Impact	Potential dispersion of zinc ion into ground and surface water	None, if appropriate control equipment is installed on recovery facilities.	
Problems and Comments	The industry is acutely aware of leaching problem. Practically all the sludge is being disposed off properly.	Preferrable technology from environmental standpoint both directly and indirectly.	
Compatibility with Existing Facilities	Compatible	Installation of on-site recovery facilities may be impossible due to space limitations.	
Monitoring and Surveillance Techniques	Monitoring of ion concentration at landfill sites	Appropriate control of streams from the recovery process	
Installation Time for New Facility	Variable depending on locations; Up to 1 to 2 years	1 Year	
Energy Requirements	Minimal	Minimal	

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(1) The selection of disposal technology is a matter of economics. It varies not only from plant to plant but in time at the same point in function of the variations of market prices for zinc and zinc salts.

(2) Recovery takes two forms, on-site and off-site. From technology standpoint the two course are equivalent.

Source: Foster D. Snell, Inc., analysis of company interviews.

6. COST ANALYSIS FOR THE TREATMENT AND DISPOSAL OF POTENTIALLY HAZARDOUS WASTES IN THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY, SIC 282

The cost analysis is presented illustratively. As explained several times in this report, the existence of a well-defined and self-contained production facility for most of the products of this industry is the exception rather than the rule. At most locations facilities are shared with those required to handle the wastes of other products. These "co-products" may belong to the SIC 282 or in entirely different classifications.

A case in point is the generally practiced method of incineration of the organic wastes, particularly liquids. Seldom does the magnitude of streams created by the production of a given resin (e.g., polypropylene) at one site justify the installation and operation of the appropriate treatment and disposal equipment.

Thus, the streams, whether solid or liquid, potentially hazardous or non-hazardous in the sense of this study, are handled as a part, most often small, of the general treatment and disposal system of the production site.

For example one particularly cooperative interviewee provided incineration cost figures calculated at several dollars per pound incinerated. Further inquiry revealed that the reported costs were those of the total incineration facility at the site. The particular streams of interest constituted only a minute fraction of the load of the facility. The same observation applies to wastewater treatment facilities and, therefore, to the disposal of sludge generated.

The estimates presented were prepared on an engineering basis, using accepted engineering format. No attempt was made to prepare estimates which would reflect impact on the financial statements of individual companies. Inclusion of tax considerations, product pricing, and other such factors would involve practices unique to each company and should be recognized as beyond the scope of this report.

Wherever possible, the figures have been cross checked with actual experience in the field as reported by the firms interviewed. However, it must be stated again that this analysis remains purely illustrative.

Bearing in mind the above discussion, evaluation of the costs have been made using the factors outlined below. The section following presents individual case studies for the costs of treatment and disposal of potentially hazardous wastes generated by this industry.

6.1 Cost Elements And Treatment Of Costs

For the purposes of this study, two kinds of costs are presented:

- Investment costs
- Annual costs.

The development and treatment of these costs are presented in the following paragraphs, supplemented where necessary by further information detailed in each of the individual cases beginning in Section 6.2.

6.1.1 Investment Costs

These typically represent "front end" costs incurred only once during the acquisition of the required land, buildings and equipment.

The importance of the landfill operations (land intensive) is reflected by the subcategorization of the investment costs into "land" and "other." A nominal land cost of $12,500 per 10,000 m^2 ($5,000 per acre) is used throughout, based on the results of field contacts.

6.1.2 Annual Costs

The two basic groups of annual cost are: first, an annualized cost of investment as defined above and, in this study, called "capital;" and second, other costs. The usual practice is to subdivide these other costs in terms of materials, utilities, labor, maintenance, supplies, insurance, etc.

For the purpose of this study, a different characterization is used:

- Capital
- Operating
- Contractor
- Energy and power.

This reflects the different nature of the operations involved and the particular interest of the EPA. The composition of these cost elements is indicated below.

6.1.2.1 Capital Cost (Annual)

This is a conversion of the investment cost to an annual sum by application of the conventional Capital Recovery Factor as given in standard accounting manuals. Unless otherwise indicated, the factor used here is 0.163, corresponding to an interest of 10% for a recovery period of 10 years. Implicit is the assumption that the value of the investment is zero at the end of the period. Although this may be valid for specialized equipment (such as incinerators), it does not usually correspond to agreed practices for land and buildings. However, this assumption appears legitimate if, in particular, the land area devoted to landfill is initially calculated for a 10-year capacity. In most instances, the value of the land thus utilized is indeed nil at the end of the fill. Rehabilitation costs of landfill sites to alternative use are estimated to be well in excess of the initial land value in the majority of cases, especially for sites where potentially hazardous wastes have been placed.

6.1.2.2 Operating Costs

In this study, this includes all the variable costs (materials, labor, supplies, maintenance, etc.), except the cost of fuel or electricity.

Labor costs are taken as $15,000 per year for general non-supervisory personnel and $25,000 per year for supervisory personnel. Part-time use is prorated.

6.1.2.3 Hazardous Wastes Disposal Contractor Costs

This cost element is usually employed in lieu of operating and capital cost or as a supplement to it. It is an important element in the next chapter, Rubber Products Industry SIC 30, and its magnitude there is discussed separately. The cost used here reflects actual experience.

6.1.2.4 Energy And Power

Fuel costs are taken as $10 per barrel for fuel oil and $0.15 per liter ($0.60 per gallon) for gasoline. Natural gas is estimated at $0.09 per cubic meter ($1.25 per million BTUs).

6.2 Case Study Of Potentially Hazardous Waste Treatment And Disposal Costs

In this section, costs for the treatment and disposal of typical potentially hazardous wastes are estimated for individual products and waste streams based on the technologies defined in Section 5. The following list details the products or categories for which the costs were developed and the tables summarize the estimates for each of the products.

- Liquid Wastes From Phenolic Resin Production--Table II-55
- Solid And Semi-Solid Wastes From Phenolic Resin Production -- Table II-57
- Still bottoms generated from the production of
  - Styrene Butadiene Rubber -- Table II-58
  - Polystyrene -- Table II-59
  - Acrylonitrile Butadiene Styrene -- Table II-60
  - Polypropylene -- Table II-61
  - Polybutadiene -- Table II-62
- Zinc sludges from the production of
  - Rayon Fibers -- Table II-66
  - Acrylic Fibers -- Table II-69.

Detailed costs are not provided for the treatment and disposal of solid and liquid wastes from amino resin production because these costs are small and production techniques are so varied that even illustrative examples would not be valid.

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For each of the products presented above, wherever applicable, the three levels of technology or variations are also taken into consideration.

6.2.1 Costs Of Treatment Disposal Of Liquid Wastes In Phenolics Production

The present practice is to incinerate the water waste stream containing 10% to 15% organics, with additional fuel required to support combustion. This practice is adequate from the standpoint of direct environmental impact. However, it requires a considerable amount of fuel to convert the water into steam during or prior to the combustion process.

The costs elements are:

- Incineration: The cost of an incinerator of the required capacity is estimated at about $1,000,000 installed, according to industry contacts.
- Annualized capital ($1,000,000 x 0.163) = $163,000
- Labor (4 man-years) = $60,000.
- Fuel: The fuel requirements vary from zero, if the stream contains more than 12% organics, to about 2,400 barrels, if it contains 5% organics. For this latter case a cost of $24,000 per year for fill may be encountered.

Costs are summarized in Table II-55.

6.2.2 Costs Of Treatment And Disposal Of Solid And Semi-Solid Waste Streams In Phenolics Production

- Level I. The present practice is to store the material in drums or in secure containment until development of suitable technology.
- Level II. Incineration, made possible by the production (at the same site) of large amounts of other materials with which the stream is mixed.
- Level III. This is proprietary technology, said to be under development. None presently available.

TABLE II-55

PHENOLICS PRODUCTION: TYPICAL PLANT DISPOSAL COSTS FOR POTENTIALLY HAZARDOUS LIQUID WASTES -- SIC 2821

Typical Plant	Production Rate	Location	Process
Phenolic Resins	15 KKKg/yr.	Eastern U.S.	Condensation

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Liquid fraction from reactor condensate	Water - 85-95% organics 5-15% (phenols, formaldehyde and other organics)	Liquid	8000 KKg/yr.

	Dollars(1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	negligible	negligible	No technology currently available
Other	1,000,000	1,000,000	
Total Investment	1,000,000	1,000,000	
Annual Costs			
Cost of Capital	160,000	163,000	
Operating Costs	60,000	60,000	
Energy and Power	24,000	24,000	
Contractor	-	-	
Total Annual Costs	244,000	247,000	
Cost/KKg of Product	16.3	16.3	
Cost/KKg of Waste	30.5	30.5	

Treatment/Disposal Technology

Level I	Incineration with additional fuel
Level II	Same as Level I
Level III	Same as Level I

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

The cost elements are:

- Drum storage: Each drum contains about 200Kg (450 lbs.) of material. Thus, 5 drums are required per ton of product; that is, 4,500 drums per year. The costs are estimated at $3.25 per drum, covering the cost of the drum, the handling and the value of the storage space. Thus, the cost is estimated at $16.25 per ton or about $15,000 per year.

- Incineration: In this example, the stream to be incinerated represents 5% of the capacity of the incinerating system. Therefore, a capacity of 18,000 KKg of incineration per year is required. The costs are allocated back on the basis of 5% utilization of the capacity. The cost of the required incinerator is estimated at a total of $4,000 000. It requires four-man operation and one supervisor. Total labor costs: $85,000. Auxiliary fuel required is estimated at 5 barrels per day. Maintenance (at 1% of installation) costs $40,000 per year. The fuel costs would thus be about $12,000 per year. The share borne by the incineration of the subject stream is given in the following table.

Table II-56 -- Incineration Costs In Phenolics Production

Investment ($4,000,000 x 0 05)	$200,000
Cost of capital ($200,000 x 0.16)	32,000
Operating cost ($125,000 x 0.05)	6,250
Fuel cost ($12,000 x 0.05)	600
Total	$238,850

- Proprietary Technology Development: The technology for this level is reported under development. Costs and other data are highly proprietary. It should, however, present a substantial economic advantage over present practice.

Costs are summarized in Table II-57.

6.2.3 Costs Of Treatment And Disposal Of Still Bottoms In A SBR Plant

All that is required for the environmentally adequate disposal of this waste is the existence of a large enough pool of mixed material to be burned (incinerated) so that the flame adjustment does not have to be changed frequently.

TABLE II-57

PHENOLICS PRODUCTION: TYPICAL PLANT DISPOSAL COSTS FOR POTENTIALLY HAZARDOUS SOLID AND SEMI-SOLID WASTES -- SIC 2821

Typical Plant	Production Rate	Location	Process
Phenolic Resins	15 KKKg/yr.	Eastern U.S.	Condensation

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Solid sediments from realtor condensate	Varying amounts of products solvents and water	Putty like substance	900 KKg/yr.

	Dollars (1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	-	-	No technology currently available
Other	-	200,000	
Total Investment	-	200,000	
Annual Costs			
Cost of Capital		32,000	
Operating Costs	15,000	6,250	
Energy and Power	-	600	
Contractor	-	-	
Total Annual Costs	15,000	38,850	
Cost/KKg of Product	1.0	2.59	
Cost/KKg of Waste	16.	43.2	

Treatment/Disposal Technology

Level I	Drum storage
Level II	Incineration together with other materials
Level III	None available

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

The cost elements are:

- The average plant may have to burn about 5.6 Kg of still bottoms per 1,000 Kg of product. With a production of 60.4 KKKg per year, this represents about 200,000 Kg of product per day or 1,000-1,500 Kg of still bottoms. This is 1,500 liters per day (400 gallons per day) or almost 8 drums.
- The required incinerator is comparatively very small. The cost is about $50,000 installed. It requires less than 1/4 man-day for operations. No significant auxiliary fuel is required and less than $1,000 per year of maintenance is necessary.

It is to be noted that in real life this would not necessarily be the case. The stream could in fact be disposed of:

  - As auxiliary boiler fuel
  - As a small part of a much larger feed stream to a centralized facility.

The costs presented here are illustrative and are summarized in Table II-58.

6.2.4 Costs Of Treatment And Disposal Of Still Bottoms In A Polystyrene Plant

The still bottom produced in this operation is substantially similar to that for the SBR plant previously described. The production of still bottoms is about 10 Kg/KKg of product. The production is about 56 KKKg per year and about 560 KKg of still bottoms are produced. This requires an incinerator of about the same capacity as for the previous plant. However, it is assumed that it will be operated about twice as long. To account for this difference (two shifts/5 days per week instead of one shift), the labor requirements are estimated at 1/2 man-year and the maintenance costs increased to $1,500 per year.

The costs are summarized in Table II-59.

6.2.5 Costs Of Treatment And Disposal Of Still Bottoms In ABS-SAN Plant

The equipment requirements and costs are the same as for the previously described plant. The typical plant produces 130 KKKg of resin per year and disposes of 650 KKg of still bottoms per year. The equipment, operating and maintenance costs should be about the same as for the polystyrene plants. The unit costs reflect the small difference in actual production volume and quantity of wastes generated.

The costs are summarized in Table II-60.

TABLE II-58

STYRENE BUTADIENE RUBBER: TYPICAL PLANT DISPOSAL COSTS FOR POTENTIALLY HAZARDOUS STILL BOTTOMS -- SIC 2822

Typical Plant	Production Rate	Location	Process
Styrene butadiene rubber	60.4 KKKg/yr.	Gulf Coast	Polymerization 50% solution 50% emulsion

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Still bottoms from monomer and solvent recovery	Organics Aromatics	Liquid	362.4 KKg/yr.

	Dollars (1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	negligible	negligible	negligible
Other	50,000	50,000	50,000
Total Investment	50,000	50,000	50,000
Annual Costs			
Cost of Capital	8,000	8,000	8,000
Operating Costs	5,000	5,000	5,000
Energy and Power	negligible	negligible	negligible
Contractor	-	-	-
Total Annual Costs	13,000	13,000	13,000
Cost/KKg of Product	0.22	0.22	0.22
Cost/KKg of Waste	35.9	35.9	35.9

Treatment/Disposal Technology

Level I	Controlled incineration
Level II	Controlled incineration
Level III	Controlled incineration

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

TABLE II-59

POLYSTYRENE: TYPICAL PLANT DISPOSAL COSTS FOR POTENTIALLY HAZARDOUS STILL BOTTOMS -- SIC 2821

Typical Plant	Production Rate	Location	Process
Polystyrene	55.9 KKKg/yr.	Ohio	Polymerization

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Still bottoms	Organics Aromatics	Liquid	559 KKg/yr.

	Dollars (1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	negligible	negligible	negligible
Other	50,000	50,000	50,000
Total Investment	50,000	50,000	50,000
Annual Costs			
Cost of Capital	8,000	8,000	8,000
Operating Costs	9,000	9,000	9,000
Energy and Power	negligible	negligible	negligible
Contractor	-	-	-
Total Annual Costs	17,000	17,000	17,000
Cost/KKg of Product	0.30	0.30	0.30
Cost/KKg of Waste	30.4	30.4	30.4

Treatment/Disposal Technology

Level I	Controlled incineration
Level II	Controlled incineration
Level III	Controlled incineration

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

TABLE II-60

ABS-SAN RESINS: TYPICAL PLANT DISPOSAL COSTS FOR POTENTIALLY HAZARDOUS STILL BOTTOMS -- SIC 2821

Typical Plant	Production Rate	Location	Process
ABS-SAN	130 KKKg/yr.	Ohio	Polymerization

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Still bottoms	Aromatics and other Organics	Liquid	650 KKg/yr.

	Dollars(1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	-	-	
Other	50,000	50,000	50,000
Total Investment	50,000	50,000	50,000
Annual Costs			
Cost of Capital	8,000	8,000	8,000
Operating Costs	9,000	9,000	9,000
Energy and Power	negligible	negligible	negligible
Contractor	-	-	-
Total Annual Costs	17,000	17,000	17,000
Cost/KKg of Product	0.13	0.13	0.13
Cost/KKg of Waste	26.1	26.1	26.1

Treatment/Disposal Technology

Level I	Controlled incineration
Level II	Controlled incineration
Level III	Controlled incineration

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

6.2.6 Cost Of Treatment And Disposal Of Still Bottoms In A Polyproplyene Plant

Here again the costs presented are illustrative. At an integrated production site, for instance, it was found that the incinerator used for the liquid organic wastes had a capacity of 6,500 KKg per year; had cost $3,200,000 (1974 dollars); and had an operating cost (excluding capital cost of $160,000 per year. Thus, in the terms of this study, it had an annual cost of $672,000 per year. With the average polypropylene installation used for this study, 933 KKg of still bottoms would be produced by the polypropylene unit. The prorated costs would then be about $96,000 for this particular site. It is to be noted that, of these costs, $62,000 are costs of capital, as computed for this study. These figures differ considerably from those which were allocated to the polypropylene stream at that location.

Should an installation be provided for the estimated still bottom stream of 933 KKg per year, it is estimated that a comparatively small burner--3,000 Kg per day or, say, $3,000 per day (150 gallons)--could be used. A unit of this type would probably cost about $75,000. Given 1/2 man-year of operation and about $1,500 per year of maintenance, the operating cost would be about $9,000 per year. The cost of capital would be $12,000, and the total annualized costs would be $21,000.

These costs are summarized in Table II-61.

6.2.7 Cost Of Treatment And Disposal Of Still Bottoms In A Polybutadiene Plant

Again, the polybutadiene production facility would in reality be part of a large production complex of which it would constitute only one unit; it would share feedstock and services with the other utilities.

However, in this case, the extreme smallness of the still bottom stream, estimated at only 4.8 KKg per year, would permit another solution.

Such a small stream cannot justify the installation of an incinerator in the hypothetical case of a single standing plant. In this case the practice would be to contract the incineration. In another study, currently being performed for the EPA, Foster D. Snell has obtained data indicating an average national cost of $0.12-0.15 per gallon for contract incineration of combustible liquid waste. This averages to about $50 per KKg of waste and is the basis of the costs presented in Table II-62.

TABLE II-61

POLYPROPYLENE: TYPICAL PLANT DISPOSAL COSTS
FOR POTENTIALLY HAZARDOUS STILL BOTTOMS
-- SICS 2821 and 2824

Typical Plant	Production Rate	Location	Process
Polypropylene	93.3 KKKg/yr.	Texas	Polymerization

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Still bottoms	Organics Aliphatics	Liquid	933 KKg/yr.

	Dollars (1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	negligible	negligible	negligible
Other	75,000	75,000	75,000
Total Investment	75,000	75,000	75,000
Annual Costs			
Cost of Capital	12,000	12,000	12,000
Operating Costs	9,000	9,000	9,000
Energy and Power	-	-	-
Contractor	-	-	-
Total Annual Costs	21,000	21,000	21,000
Cost/KKg of Product	0.22	0.22	0.22
Cost/KKg of Waste	22.0	22.0	22.0

Treatment/Disposal Technology

Level I	Controlled incineration
Level II	Controlled incineration
Level III	Controlled incineration

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

TABLE II-62

POLYBUTADIENE: TYPICAL PLANT DISPOSAL COSTS FOR POTENTIALLY HAZARDOUS STILL BOTTOMS -- SIC 2822

Typical Plant	Production Rate	Location	Process
Polybutadiene	47.7 KKKg/yr.	Texas	Polymerization

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Still bottoms	Organics Aliphatics	Liquid	4.8 KKg/yr.

	Dollars (1974)		
T/D Level	Level I	Level II	Level III
Technology	1	1	
Investment Costs			
Land	-	-	-
Other	-	-	
Total Investment	-	-	-
Annual Costs			
Cost of Capital	-	-	-
Operating Costs	-	-	-
Energy and Power	-	-	-
Contractor	250	250	250
Total Annual Costs	-	-	-
Cost/KKg of Product	0.05	0.05	0.05
Cost/KKg of Waste	50	50	50

Treatment/Disposal Technology

Level I, II, III - Contract incineration (controlled)

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

6.2.8 Costs Of Treatment And Disposal Of Sludge Containing Zinc In A Rayon Plant

In the United States six plants manufacture rayon. The typical plant produces 60 KKKg (132,000,000 lbs.) per year. Such a plant has to dispose of 12,000 KKg (26,400,000 lbs.) of zinc containing sludge per year. This represents about 10,000 m^3 (13,000 cu. yds.) of sludge per year.

This sludge contains about 10% zinc hydroxide; that is, 1,200 KKg (2,640,000 lbs.)

The cost elements are:

- Level I. This technology consists of disposal to secured landfill. The operating costs for a secured landfill at a typical production site amount to

  - Labor: \$1,500/1000 m^3
  - Fuel: \$500/100 m^3

  The investment for a secured landfill, exclusive of land, is estimated at \$125,000 per 10,000 m^2 (\$50,000/acre). This includes excavation, drainage, test wells and a prorated volume as utilized for the sludge.

  The yearly land requirement is 2,000 m^2 (0.5 acre). The landfill site is assumed to be prepared for a 10-year capacity. Thus, a land area of 20,000 m^2 (5 acres) is required. The land value is estimated at \$12,500 per 10,000 m^2 (\$5,000/acre). The cost of disposal estimated by this method is given in the following table.

Table II-63 -- Level I Disposal Costs In Rayon Production

Investment costs	
Land (20,000 m^2 @ \$1.25/m^2)	\$ 25,000
Other (20,000 m^2 @ \$12.5/m^2)	250,000
Total	\$275,000
Annual costs	
Capital costs (\$275,000 x 0.16)	\$ 44,000
Operating costs (\$2,000 @ \$1.50)	3,000
Fuel costs (\$2,000 @ \$0.50)	1,000
Total	\$ 48,000

- Level II. This involves the installation of a zinc recovery unit.

The cost of such a unit treating 20,000 m^3 per year is reported to be $2,750,000.

Using the convential engineering scaling factor, 0.6 power of the size, the cost of a recovery plant treating 10,000 m^3 of sludge per year is estimated at $1,800,000.

The operating costs of the 20,000 m^3 per year unit are reported to be $125,000 per year. These represent mostly labor costs. Thus, the cost of operating the smaller plant is estimated at $100,000. The energy costs are considered to be almost $2,000 per year.

The costs of operating the recovery unit are summarized in the following table.

Table II-64 -- Level II Operating Costs For Zinc Recovery Unit In Rayon Production

Investment costs		Negligible
Other		$1,800,000
	Total	$1,800,000
Annual costs		
Capital costs ($1,800.000 x 0.16)		$ 288,000
Operating costs		100,000
Fuel		2,000
	Total	$ 390,000

However, the plant recovers the zinc chloride. The net value of the material thus recovered (after deduction of the cost of the required hydrochloric acid and adjustment for 90% yield of recovery) is estimated at $1,100,000.

The process is reported to reduce the volume of sludge to 1/3 the original. Therefore, the disposal of 3,300 m^3 per year has to be taken into account.

Based on the same assumptions and estimates as used with regard to Level I disposal, the cost of disposing of this sludge is estimated in the following table.

Table II-65 -- Level II Disposal Costs In Rayon Production

Investment costs		
Land (7,000 m^2 @ \$1.25/m^2)		\$ 9,000
Other (7,000 m^2 @ \$12.5/m^2)		88,000
	Total	\$ 97,000
Annual costs		
Capital costs (1,897,000 x 0.16)		\$303,000
Operating costs		101,050
Fuel		2,350
	Total	\$406,400

The operation thus appears to achieve a net operating profit of about \$700,000 per year.

- Level III. Since both Level I and Level II technologies are considered environmentally adequate, they each represent Level III technologies. Therefore, Level III-technology 1 is estimated to be the same as Level I and Level III-technology 2 is the same as Level II.

All the cost data are summarized in Table II-66.

6.2.9 Costs Of Treatment And Disposal Of Zinc Containing Sludge In Acrylic And Modacrylic Plants

The typical acrylic/modacrylic processing plant has a production level of 130 KKKg (290,000,000 lbs.) per year. It produces about 26,000 KKg of zinc containing sludges. This represents about 24,000 m^3 (31,000 cu. yds.) per year.

This sludge contains about 5% of zinc hydroxide. This would represent about 1,300 KKg per year.

The disposal of this sludge is identical to disposal methods practiced in the rayon plant, as described in the preceeding sub-sections.

TABLE II-66

RAYON: TYPICAL PLANT DISPOSAL COSTS FOR ZINC CONTAMINATED SLUDGE -- SIC 2823

Typical Plant	Production Rate	Location	Process
Rayon	60 KKKg/yr.	South Eastern U.S.	Viscose

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Zinc contaminated sludge	Water 75% Solids 25% Zinc Hydroxide 10%	Gel-like	12,000 KKg/yr

	Dollars (1974)			
T/D Level	Level I	Level II	Level III	
Technology	1	1	1	2
Investment Costs				
Land	25,000	9,000	25,000	9,000
Other	250,000	1,888,000	250,000	1,888,000
Total Investment	275,000	1,897,000	275,000	1,897,000
Annual Costs				
Cost of Capital	44,000	303,000	44,000	303,000
Operating Costs	3,000	101,000	3,000	101,000
Energy and Power	1,000	2,400	1,000	2,400
Contractor	-	-	-	-
Total Annual Costs	48,000	406,400	48,000	406,400
Cost/KKg of Product	0.80	(11.7)(1)	0.80	(11.7)(1)
Cost/KKg of Waste	4.00	(58.3)(1)	4.00	(58.3)(1)

Treatment/Disposal Technology

Level I	Secured landfill
Level II	Zinc recovery and secure landfill
Level III-1	Same as Level I
Level III-2	Same as Level II

(1) This figure reflects an additional profit realized from the value of the recovered zinc chloride.

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

Using the same cost parameters, the following costs can thus be estimated:

Table II-67 -- Level I Disposal Costs In Acrylic And Modacrylic Production

Investment costs		
Land		$ 60,000
Other		600,000
	Total	$660,000
Annual costs		
Capital		$105,600
Labor		7,200
Fuel		2,400
	Total	$115,200

- Level II. Recovery

It is assumed that the plant reported is designed to handle 20,000 m^3 per year of 10% sludge and is adequate to handle 24,000 m^3 per year of 5% sludge.

It is further assumed that the same sludge volume reduction is encountered.

The value of the recovered zinc chloride is estimated at $1,220,000 per year. Therefore, the recovery costs presented in the following table result.

Table II-68 -- Level II Total Zinc Recovery Costs In Acrylic And Modacrylic Production

Investment costs		
Land		$ 20,000
Other		2,950,000
	Total	$2,970,000
Annual costs		
Capital costs		$ 475,000
Operating costs		125,000
Energy costs		3,000
	Total	$ 603,000

There is a net operating profit of $617,000.

The cost figures are summarized in Table II-69.

6.3 Costs Of Disposal Of Potentially Hazardous Wastes Affecting The Various Segments Of The Plastic Materials And Synthetics Industry, SIC 282

The costs data developed for the various individual products in the previous sections are summarized for the relevant segments of the Plastic Materials and Synthetics Industry and presented in Table II-70.

The costs are in turn expressed as a percentage of the value of the products shipped by the segments of the industry in Table II-71.

However, it must be borne in mind that these figures, for all their precision, are illustrative. They would be substantially affected by shifts in the relative importance of the various products manufactured in each segment of the industry.

Table II-72 presents a synopsis of the findings concerning the potentially hazardous waste streams, their nature, the amounts generated annually, the treatment and disposal technologies and the associated costs on a product-by-product basis.

TABLE II-69

ACRYLIC AND MODACRYLIC: TYPICAL PLANT DISPOSAL COSTS FOR ZINC CONTAMINATED SLUDGE -- SIC 2824

Typical Plant	Production Rate	Location	Process
Acrylic and Modacrylic	130 KKg/yr.	South Eastern U.S.	Wet Spinning

Identification of Waste Stream	Composition	Form	Amount To Treatment/Disposal
Zinc contaminated sludge	Water 85-90% Solids 10-15% Zinc 5%	Gel-like	26,000 KKg/yr.

	Dollars (1974)			
T/D Level	Level I	Level II	Level III	
Technology	1	1	1	2
Investment Costs				
Land	60,000	20,000	60,000	20,000
Other	600,000	2,950.000	600,000	2,950,000
Total Investment	660,000	2,970,000	660,000	2,970,000
Annual Costs				
Cost of Capital	105,600	475,000	105,600	475,000
Operating Costs	7,200	125,000	7,200	125,000
Energy and Power	2,400	3,000	2,400	3,000
Contractor	-	-	-	-
Total Annual Costs	115,200	603,000	115,200	603,000
Cost/KKg of Product	0.89	(4.75) (1)	0.89	(4.75) (1)
Cost/KKg of Waste	4.43	(23.73) (1)	4.43	(23.73) (1)

Treatment/Disposal Technology

Level I Secured landfill
Level II Recovery
Level III-1 Same as Level I
Level III-2 Same as Level II

(1) This represents a net operating profit due to the values of the recovered zinc chloride.

Source: Foster D. Snell, Inc., analysis of interviews and literature data.

TABLE II-70

YEARLY EXPENDITURES FOR POTENTIALLY HAZARDOUS WASTE DISPOSAL IN THE MAJOR SEGMENTS OF THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY BY T/D LEVEL -- SIC 282

SIC Code	Product	Production (KKKg/yr.)	Wastes (KKg/yr.)	T/D Level I Technology 1	II 1	III 1	III 2
				($ Million, 1974)			
2821	Phenolics(1)	610	361,000	10.50	11.50	11.50	N.A.
2822	Styrene Butadiene Rubber	2,116	12,700	.46	.46	.46	N.A.
2821	Polystyrene	1,844	18,440	.56	.56	.56	N.A.
2821	ABS-SAN	440	2,200	.06	.06	.06	N.A.
2821	Polypropylene	1,026	10,260	.23	.23	.23	N.A.
2824		1,170	11,700	.26	.26	.26	N.A.
2823	Rayon	360	36,000	.03	(2.10)(2)	.03	(2.10)(2)
2824	Acrylics/Modacrylics	1,390(3)	278,000	1.23	(6.60)(2)	1.23	(6.60)(2)
2821	Subtotals			11.35	12.35	12.35	12.35
2822				.46	.46	.46	.46
2823				.03	(2.10)(2)	.03	(2.10)(2)
2824				1.23	(6.60)(2)	1.23	(6.60)(2)
282	Total			13.33	4.37(4)	14.33	4.37(5)

Note: For technology definitions see individual cost tables.

(1) This represents a summation of two waste streams: liquid and solid.

(2) Net profit from zinc recovery.

(3) The wastes originate in spinnning operations only.

(4) The total reflects the net profit from zinc recovery in rayon and acrylics. Recovery is assumed at all production sites.

(5) The total includes costs of Level I technologies for those products which do not have Level III-2 technologies.

N.A. = Not Applicable.

Source: Summations of values from Tables II-55 through II-62, II-64 and II-69 and from production tables in this chapter.

Table II-71

PERCENT OF PRODUCTION VALUE ALLOCATED TO TREATMENT AND DISPOSAL OF POTENTIALLY HAZARDOUS WASTE IN THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY--SIC 282

SIC Code	T/D Level Technology	Percent Of Production Value I	II	III 1	III 2
2821		0.25	0.28	0.28	0.28
2822		0.042	0.042	0.042	0.042
2823		0.0048	(0.33) (1)	0.0048	(0.33) (1)
2824		0.034	(0.18) (1)	0.034	(0.18) (1)
Total		0.14	0.045 (1)	0.15	(0.045) (1)

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(1) These figures reflect the net profit from zinc recovery in rayon and acrylics. Recovery assumed at all production sites.

Source: Foster D. Snell, Inc. analysis of industry interviews and literature data.

Table II-72

SYNOPSIS OF THE FINDINGS ON TREATMENT/DISPOSAL METHODS AND COSTS FOR THE PLASTIC MATERIALS AND SYNTHETICS INDUSTRY--SIC 282

SIC Code	Product	Waste Stream	Quantity of Potentially Hazardous Waste Generated	Technology	T/D Level[1]	Costs[2]	
						Product	Per Plant
			(KKg/yr.)			($/KKg)	($/yr.)
2821	Phenolic Resins	Liquid fraction from reactor condensate	325,000	Incineration	I & II	16.3	224,000
		Solid sediments from reactor condensate	36,000	Storage	I	1.0	15,000
				Incineration with other materials	II-III	2.59	38,850
2822	Styrene, Butadiene Rubber	Still bottoms from monomer and solvent recovery	12,700	Incineration	I-II-III	0.22	13,000
2821	Polystyrene	Still bottoms	18,440	Incineration	I-II-III	0.30	17,000
2821	ABS-SAN	Still bottoms	2,700	Incineration	I-II-III	0.13	17,000
2821 2824	Polypropylene	Still bottoms	22,000	Incineration	I-II-III	0.22	21,000
2823	Rayon	Zinc containing sludge	7,200	Secured landfill	I-III-1	0.80	48,000
				Recovery	I-III-2	(11.7)[3]	406,400 (700,000)[4]
2824	Acrylics	Zinc containing sludge	278,000	Secured landfill	I-III-1	0.89	115,200
				Recovery	II-III-2	(4.75)[3]	603,000 (1,220,000)[4]

T/D = Treatment/Disposal

[1] See Tables II-55 through II-58, II-62, II-66 and II-69 for complete definitions of the respective T/D levels.

[2] This is the cost for a "typical" plant, at about the average production capacity for the particular product.

[3] This represents a net profit from the value of the recovered zinc.

[4] This represents the value of the recovered zinc at the typical plant.

Source: Summation of the information presented in Tables II-55 through II-62, II-66 and II-69

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